Senior Thesis

Center for the Arts
University of Delaware
Newark, DE

Rendering courtesy of Ayers/Saint/Gross Architects

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Mechanical Option
Spring 2006
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Executive Summary:

The Center for the Arts is a performing arts center located on the University of Delaware campus in Newark, Delaware. The 92,000 square foot Center for the Arts consists of a Proscenium Theater, Recital Hall, Orchestra Rehearsal, and Theater Rehearsal as the major performing spaces as well as 32 practices rooms.

An underfloor air distribution system utilizes a plenum space between the structural slab and the underside of a raised floor to distribute the conditioned air to the room. An underfloor air distribution system creates a stratified condition where the natural buoyancy of air removes heat and contaminates from the occupied zone.

The Trane program Trace 700 is used to determine the loads and airflow for the Proscenium Theater. The underfloor air distribution system increases the airflow to 14,200cfm and decreases the cooling coil load to 315Mbh. The minimum required outdoor air as specified from ASHRAE Standard 62.1-2004 is cut in half to 22% for the underfloor system.

A four-foot elevated slab will create a plenum for the Proscenium Theater seating levels. The plenum on the first level will require the foundation to be depressed four feet from the original design. The structural support of the balcony will remain at the designed height and the elevated slab, creating the plenum, will be built on top of designed balcony. The additional weight of the elevated slab will increase the beam sizes to W16x31 and the columns to W10x60.

Meeting the acoustical requirements within the Proscenium Theater is of great importance to the owner, the University of Delaware, to preserve the performance quality of the space. With the switch to an underfloor air distribution system the Proscenium Theater has an NC rating of NC-16, which remains within the acceptable limits for noise criteria set forth by the University of Delaware and Kirkegaard Acoustical Consultants.

University of Delaware Center For The Arts

Newark, DE

Project:

Owner: University of Delaware
Architect: Ayers / Saint / Gross
CM: Whiting Turner
MEP Engineer: Mueller Associates
Structural Engineer: McLaren Engineering Group
Civil Engineer: Tetra Tech
Acoustical Consultant: Kirkegaard

Building Description:

Performing arts center which in includes a proscenium theatre, recital hall, music rehearsal hall, theatre rehearsal room, practice rooms and administrative offices.

Structural:

Concrete Spread Footings and 5" concrete slab on grade

2" isolation joint at performance space walls

Steel columns at lobby and seating support

Rectangular concrete columns at typical interstitial spaces

Concrete slabs floor construction supported by concrete walls or steel beams

Concrete roof slab on metal deck supported by steel structure

Mechanical:

Steam Heating and Chilled Water cooling provided via campus central distribution systems

6 AHU's located on 2nd level

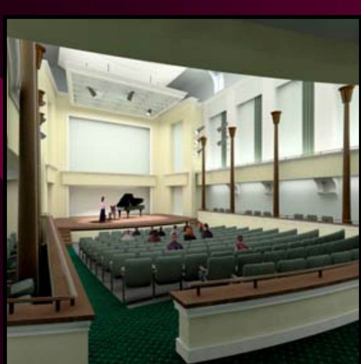
Gas-fired steam generator to provide year round humidity control

Electrical:

Supply: 1600A, 480Y/277V, 3PH, 4W

Transformers: (13) 480V Delta to 208Y/120V, 3PH, 4W

Emergency Generator located in adjacent parking garage



Construction:

Size: 92000 SF
Stories: 2 Above Grade
Delivery Method: Design-Bid-Build
Total Cost: $36.2 Million
Construction: June 2004 – May 2006

Karen Schulte

Mechanical Option

http://www.arche.psu.edu/thesis/eportfolio/current/portfolios/kes242/

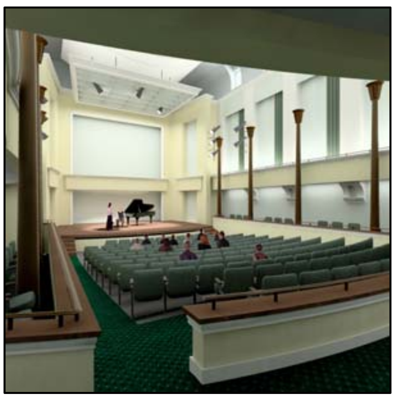
Introduction

Project Background:

Building Name: Center For The Arts
Location and Site: Newark, Delaware
Occupant Name: University of Delaware
Occupancy or Function Type: Assembly Spaces (A-1)
Size: 92110 SF
Number of Stories: 2 Above Grade and 1 Basement

Primary Project Team:

- Owner:
  - University of Delaware
- Architects:
  - Ayers/ Saint / Gross Architects and Planners
  - http://www.asg-architects.com
- Construction Managers:
  - Whiting Turner Contracting Company
  - http://www.whiting-turner.com/
- MEP and Fire Protection Engineers:
  - Mueller Associates Inc.
  - http://www.muellerassoc.com
- Structural Engineers:
  - McLaren Engineering Group
  - http://www.mgmclaren.com/
- Civil Engineers:
  - Tetra Tech Inc.
  - http://www.tetratech.com
- Acoustical Consultants:
  - Kirkegaard Associates
  - http://www.kirkegaard.com



Recital Hall

Dates of Construction: June 2004 – August 2006
(Commissioning beginning in June 2006)

Cost Information: $36.2 million

Project Delivery Method: Design-Bid-Build

Major National Codes:

- IBC 2000 Edition
- International Plumbing Code 2000 Edition
- NFPA 101, Life Safety Code 2000 Edition

Orchard Street Lobby

Zoning: The University is exempt from zoning by a charter in the City of Newark. The zoning is designated UN for University. As long as the University operates as an educational facility (classrooms, etc, - CFA applies) then this exception applies.

Historical Requirements: Previously the land was a parking lot and four houses that were used by the University for offices.

Building Systems:

Building Envelope:

The building is enclosed by brick with predominately nine foot high windows on the first floor and six foot high windows on the second floor. There are wood entry doors into the main lobby of the Center for the Arts along the east side of the building. The roof above the east lobby is sloped with dormers. The visible portions of the roof from ground level are slate shingles and the flat roof over all of the performance spaces is Mod. Bitumen B.U. roof system with composite insulation.

Construction:

The Center for the Arts Building (CFA) is the second bid package in a three-bid package set. The first bid package was the adjacent parking garage and the third, yet to be designed and bid, is an additional concert hall to be added onto the southwest side of the building. Each of the performance spaces in the CFA has 2" open joint complete separation between structural systems for vibration and noise isolation.

Electrical / Lighting:

The adjacent parking garage contains a pad mounted transformer, 2500kVA 12.47kVA primary, 480Y/277V-secondary, that then supplies the CFA through an 8-way ductbank from the parking garage to an electrical manhole. There are thirteen transformers in the CFA that supply 208/120V 3-phase 4-wire power to the building. There is an emergency generator located in the parking garage to serve the emergency and stand-by loads for the parking garage, CFA and future concert hall. The lighting in the CFA is a variety of pendant, wall-mounted and recessed fluorescent light fixtures.

Mechanical:

The CFA has six air-handling units, four dedicated for specific space: one supplies the Public Lobby, one supplies the Proscenium Theatre, one supplies the Proscenium Stage and one supplies the Recital Hall. Three of the air-handling units that service a single zone are constant volume systems and the two units that service multiple spaces are variable air volume units. The other unit is an under floor displacement air distribution system. The heating system and chilled water system are branches off the campus steam and chilled water mains.

Structural:

The structural system for the Center for the Arts Building is composite concrete on metal deck supported by structural steel. Because of the differing sizes and shapes of the performance, spaces there is not a typical beam size or length throughout the building but the beams and girders are primarily wide flange. The majority of the columns in the building are W10x33's but range from W10x33 to W14x61. Under the performance spaces, there is 5" slab on grade above a 3' think concrete mat. Under the other spaces there are the concrete spread footing and the 5" slab on grade.

Fire Protection:

The Center for the Arts Building has an automatic sprinkler system and fire alarm and detection systems. The performance spaces are protected by hydraulically designed wet pipe sprinkler system. Each floor will be a separate sprinkler zone. The performing arts theatre stage will have a proscenium curtain constructed of an approved non-combustible material. The stairwells all have one-hour fire separation. Between the basement offices and storage rooms and the performance spaces there is a 2 hour floor/ceiling rating.

Transportation:

Three staircases serve the first floor to the second floor. Two staircases serve from the basement level up to the gallery level of the Proscenium stage. There are three elevators to provide ADA accessibility to the second level.

Telecommunication:

The practice rooms on the second level are designed so that computer-synthesizing equipment can be brought in and used. There is also an electronic/computer room for mixing and recording music.

Mechanical Design

Existing Mechanical System Design:

The Center for the Arts is a performing arts center located on the University of Delaware campus in Newark, Delaware. The 92,000 square foot Center for the Arts consists of a Proscenium Theater, Recital Hall, Orchestra Rehearsal, and Theater Rehearsal as the major performing spaces as well as 32 practices rooms.

The primary factor contributing to the mechanical system design is the use of the spaces and their acoustical sensitivity. The choice of air delivery to the performing spaces plays a significant role in providing patron comfort and determining architectural volume and acoustical response times. Each of the performing spaces must meet the noise criteria specified by the University of Delaware. The noise criteria allowable noise levels affect the equipment selection and sizing.

Air Handling Units

AHU-1

Air-Handling Unit 1 is a variable air volume unit that supplies 19,200cfm to 19 zones. This air-handling unit serves the Orchard Street lobby on the south side of the building as well as corridors and interior spaces. According to ASHRAE Standard 62.1-2004, the minimum outdoor air percentage was found to be 35%. In order to comply with ASHRAE Standard 62.1 the scheduled minimum amount of outdoor is 6700cfm.

AHU-2

Air-Handling Unit 2 is a constant air volume unit that serves the Proscenium Theatre seating area and supplies 7,900cfm to that single zone. According to ASHRAE Standard 62.1-2004, the minimum outdoor air percentage was found to be 44%. In order to comply with ASHRAE Standard 62.1 the scheduled minimum amount of outdoor air is 4,000cfm.

AHU-3

Air-Handling Unit 3 is a constant air volume unit that the serves the Proscenium Theatre stage supplies 9,450 cfm to that one zone. According to ASHRAE Standard 62.1-2004, the minimum outdoor air percentage was found to be 8%. In order to comply with ASHRAE Standard 62.1 the scheduled minimum amount of outdoor air is 950 cfm.

AHU-4

Air-Handling Unit 4 is a variable air volume unit that supplies 35,000cfm to 62 zones. This air-handling unit serves the theatre rehearsal and back of the house interior spaces on the lower level, and practice rooms on the second level. According to ASHRAE Standard 62.1-2004, the minimum outdoor air percentage was found to be 33%. In order to comply with ASHRAE Standard 62.1 the scheduled minimum amount of outdoor air is 11,700cfm.

AHU-5

Air-Handling Unit 5 is a constant air volume unit that supplies 10,500cfm to one zone through an under floor distribution system. This air-handling unit serves the Recital Hall seating area and stage. According to ASHRAE Standard 62.1-2004, the minimum outdoor air percentage was found to be 17%. In order to comply with ASHRAE Standard 62.1 the scheduled minimum amount of outdoor air is 1,800cfm.

AHU-6

Air-Handling Unit 6 is a constant air volume unit that supplies 7,000cfm to one zone. This air-handling unit serves the Orchestra Rehearsal room. According to ASHRAE Standard 62.1-2004, the minimum outdoor air percentage was found to be 42%. In order to comply with ASHRAE Standard 62.1 the scheduled minimum amount of outdoor air is 3,000cfm.

Chilled Water System

The chilled water for the Center for the Arts is supplied from the campus chilled water mains. There are two pumps, located in the lower level mechanical room, that each has a dedicated variable frequency controller to modulate the speed of the pump in order to maintain adequate system differential pressure. The pumps pump the chilled water to the cooling coils in the air handling units and the fan coil units that cool the electrical equipment room.

Heating Water System

The heating system for the Center for the Arts is supplied from the campus steam mains. The steam enters the Center for the Arts as medium pressure steam then reaches a pressure reducing station where the steam is converted to low pressure steam. The low-pressure steam is then converted to 200°F water in one of the two steam-to-water converters. There are two pumps, located in the lower level mechanical room, that each has a dedicated variable frequency controller to modulate the speed of the pump in order to maintain adequate system differential pressure. The heating water is then pumped throughout the building supplying heating water to the air-handling unit preheat and reheat coils, the unit heaters, duct mounted reheat coils and other equipment.

Humidification System

Each of the six air handling units that service the Center for the Arts are equipped with a gas fired steam humidifier. Humidification control is vital to the performance quality within the spaces in the Center for the Arts. Changes in humidity levels affect the tonal quality of tuned instruments. Each of the performance spaces is equipped with humidity sensors so that the humidity levels can be maintained.

Proscenium Theater Existing Mechanical Design:

The Proscenium Theater contains seating for 500 occupants on two levels. The front two rows of seating on the first floor can be either for patrons or for an orchestra. When the orchestra uses the front two rows, those rows are hydraulically lowered to a storage area and a ten-foot vertical opening is left for the orchestra to play out of.

The ventilation air for the Proscenium Theater is supplied by air handling units 2 and 3. Air handling unit 2 provides air for the seating area and air-handling unit 3 provides air for the stage of the Proscenium Theater. The seating area air is supplied from a constant volume unit that delivers air to occupants from forty feet above the occupants breathing zone. The overhead diffusers are located above the catwalk level. Directly below the overhead diffusers there is a sound lined board so that the air falls over the edges to reduce the dumping effect.

The theater contains a 180-seat balcony that hangs over the back three rows of the first floor seating area. In order to accommodate the ventilation requirements for the occupants under the balcony there are linear slot diffusers along the back wall of the theater seating area.

In the four corners of the Proscenium Theater seating area there are return airshafts. On the first level, the return grilles are located in the back two corners of the seating area. On the balcony level, the return grilles and plenums are located in the front corners closest to the stage. From each of the return air plenums on their respective levels the air is ducted up to the gallery level where the return air exits the theater and is taken back to the air-handling unit.

Underfloor Air Distribution:

An underfloor air distribution system utilizes a plenum space between the structural slab and the underside of a raised floor to distribute the conditioned air to the room. An underfloor air distribution system creates a stratified condition where the natural buoyancy of air removes heat and contaminates from the occupied zone. Diffusers located in the elevated floor slab distribute air to the room from the plenum. Since the diffusers are located in the floor, the supply air temperatures must be warmer then the conventional overhead air distribution systems because of the immediate proximity of the supply air to the occupied zone. For cooling the supply air temperature should range from 63°F- 68°F, this temperature range will prevent overcooling the occupants of the space.

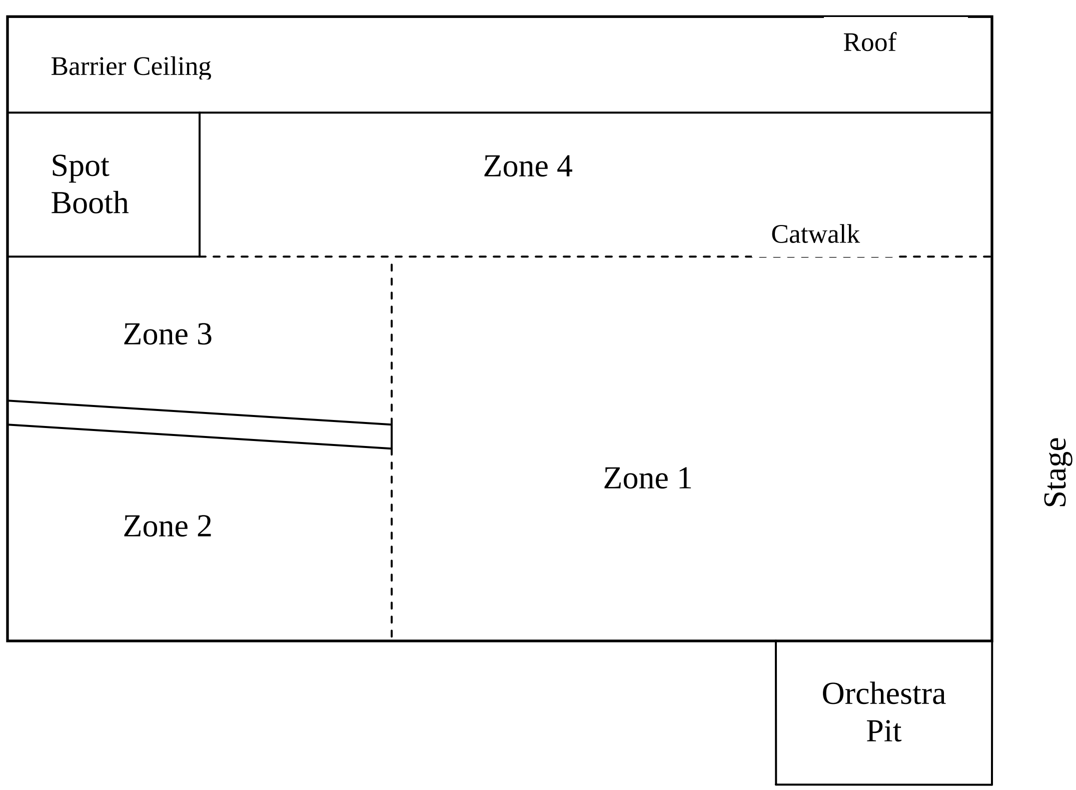
The potential benefits that occur as a result of the implementation of underfloor air distribution include increased thermal comfort, better indoor air quality, reduced outdoor airflow, reduced floor to floor heights, and reduced supply fan horsepower. The increase in thermal comfort arises from the fact that the supply air temperature is higher then conventional overhead distribution systems and the floor diffusers induce local circulation and mixing in the occupied zone to a relatively uniform temperature. The improvements in indoor air quality result from natural flow of air in the underfloor system as compared to the overhead air distribution system. In the overhead system the contaminants in the air that collect at the ceiling level, due to the natural buoyancy of air, are forced back into the breathing zone by the induced mixing of ceiling diffusers to create a uniform environment. In underfloor systems, the air supplied at the floor naturally forces the contaminants to the ceiling level where natural buoyancy and stratification keep the contaminants from re-entering the breathing zone. The air change effectiveness of underfloor systems is higher therefore; less outdoor air is needed for ventilation. This decrease in minimum required outdoor air equates to an energy savings on conditioning less outdoor air. The use of the plenum eliminates supply ducts, terminal units and diffusers in the ceiling space leaving ample room for the other trades in the ceiling space and offering the possibility of decreasing the floor-to-floor heights. The decrease in amount of supply air duct due to the use of the plenum also cuts down on the static pressure that the supply air fan must overcome. Less static pressure results in less horsepower needed to power the supply air fan.

The Proscenium Theater design will utilize a pressurized plenum with passive diffusers to supply the theater with air. When designing an underfloor air distribution system there is a choice of using a pressurized plenum or a zero-pressure plenum. With the pressurized plenum the plenum maintains a slightly higher pressure then the conditioned space usually in the magnitude of 0.05 – 0.1 in WG. The biggest problem with pressurized plenums is the issue of leakage through floor panels. In the Proscenium Theater, the diffusers will be located in the concrete slab and not in a raised access floor. Therefore air leakage through the panels or due to a panel being removed will not be a problem. In order to supply air utilizing a zero-pressure plenum the diffusers must be fan powered active diffusers. The use of fans at all the diffuser locations would introduce increased noise levels to a level above the specified limit of RC 18-22.

Proscenium Theater Load Calculations:

In order to model the Proscenium Theater and determine the ventilation and cooling load requirements Trane's Trace 700 program was used. There is not yet a program that will model a space for underfloor air distribution. Currently the Center for Built Environment at the University of California is working on developing a UFAD system simulation program. This technology is not fully developed or available to the public so Trace 700, designed to model conventional overhead systems, was used.

Since Trace 700 will not model for underfloor distribution situations when using the software for the underfloor loads, the space was broken up into zones in order to try to create a scenario similar to what actual conditions will be. One of the characteristics of underfloor distribution, as opposed to overhead distribution, is temperature stratification. In an effort to create this in the Trace program, the Proscenium Theater is broken up into five zones.



Zone 1 is the first level seating area that is not under the balcony. Zone 2 is the first level seating area under the balcony. Zone 3 is the balcony seating area. Zone 4 is the plenum above all the seating areas. Zone 5 is the orchestra pit.

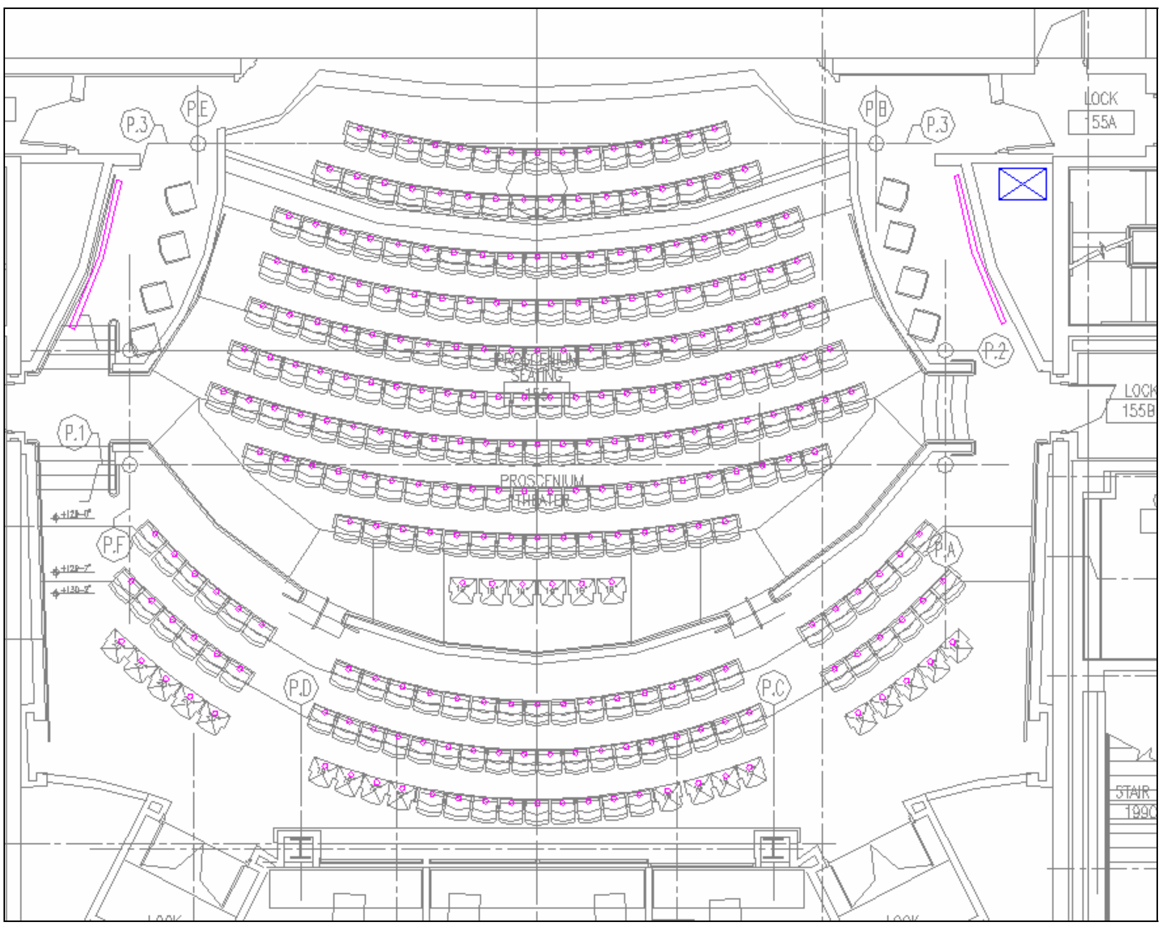
The Proscenium Theater is an interior space and the only exterior walls on the theater are once the theater reaches a height above the rest of the Center for the Arts building. Zone 4 contains the entire exterior wall load, the roof load, and the lighting load from the lights at the catwalk level. All the other zones only have the lighting load from lights located in the respective zone and the people loads. The purpose of breaking up the theater in this fashion was to determine the temperature of the air at the top of the room where the return grilles are located. If you enter the theater as one room, Trace will not account for the fact that the air is supplied at the floor and returned at the ceiling and the temperature stratification that results. The loads accounted for in zone 4 are directly routed back to the air handling unit through the return air path.

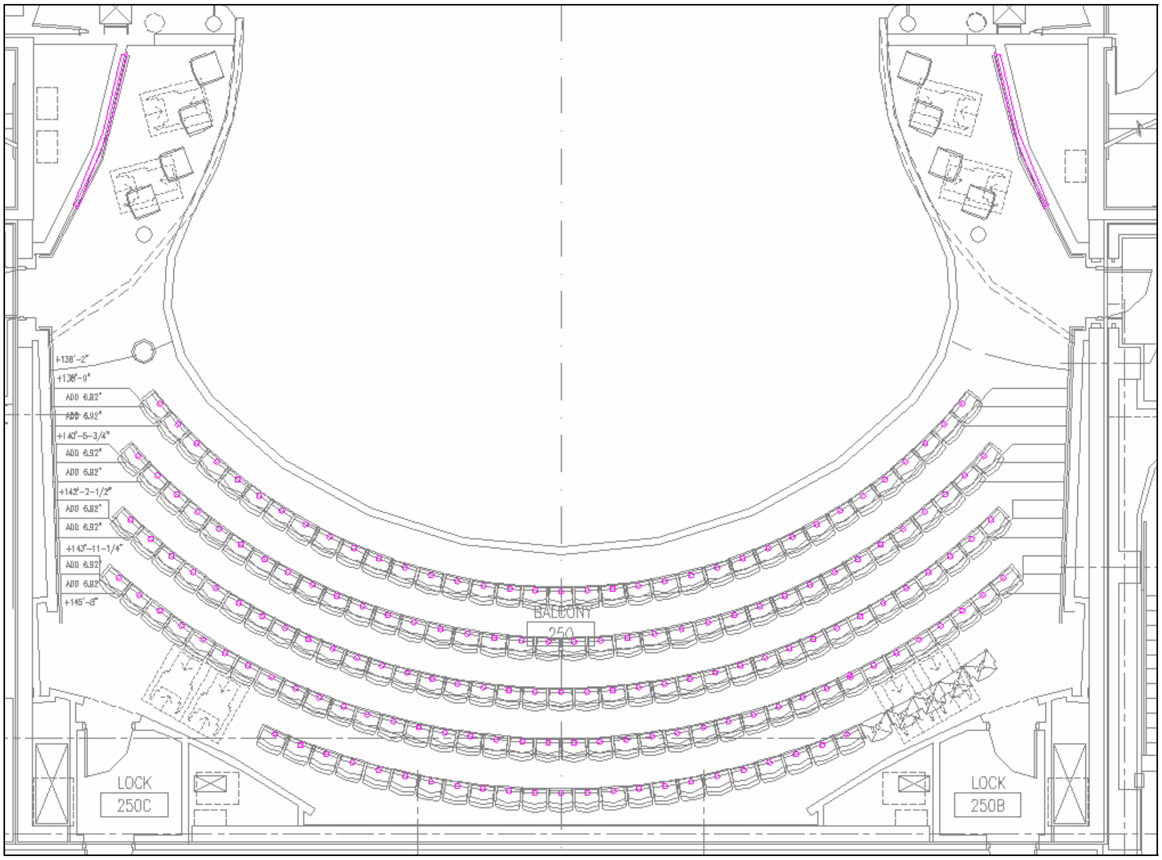
The printouts of the Trace 700 load outputs are located in Appendix A. The Trace outputs call for 14,200 cfm of supply air producing a 310Mbh total capacity of the cooling coil.

Even though the required airflow increased from 7900 cfm to 14,200 cfm the ASHRAE Standard 62.1 minimum required outdoor air quantity decreases. Underfloor air distribution allows the zone air distribution effectiveness to increase from 1.0 to 1.2 because there is a floor supply of cool air and ceiling return. The increase in zone air distribution effectiveness results in a 17% decrease in the zone outdoor airflow value, V_{oz}. The system ventilation efficiency increases from 0.8 to 0.9 for the underfloor system because the maximum outdoor air fraction decreases to 0.16 for the Theater under the new underfloor system. The net result of these changes is a 50% reduction in minimum required outdoor air from 44% for the overhead distribution to 22 % for the underfloor distribution. See Appendix B for a comparison of ASHRAE Standard 62.1 of the two systems.

Diffuser Selection and Layout:

The plenums in the Proscenium Theater, first level and balcony level, are four feet deep and there are 8in swirl diffusers for the air to be supplied through. The swirl diffusers will be Nailor Industries Inc. Floor "Swirl" Diffusers model NFD. (Specification in Appendix C) One swirl diffuser will be located under ever seat in the Proscenium Theater. In order to ensure that the location of the diffusers does not conflict with the placement of the seats in the Theater the seats will be installed before the holes are bored into the concrete elevated slab. Since the placement of the holes in the slab for the diffusers is occurring after the pouring of the concrete it is crucial for the structural stability if the slab that the diffuser holes not cut through the rebar reinforcing.





In order to fill the plenum with conditioned air, the air is ducted from the air-handling unit in the second floor mechanical room to the plenums. All of the ducts in the plenum will sit on duct stands and not the concrete slab. Once in the plenum the duct branches out throughout the plenum to bellmouth openings where the air is supplied to the plenum at 200 fpm. The diffusers will be permanently set to supply the specified amount of air as determined through from the Trace loads; plans in Appendix D specify cfm levels per zone.

Air Handling Unit Changes:

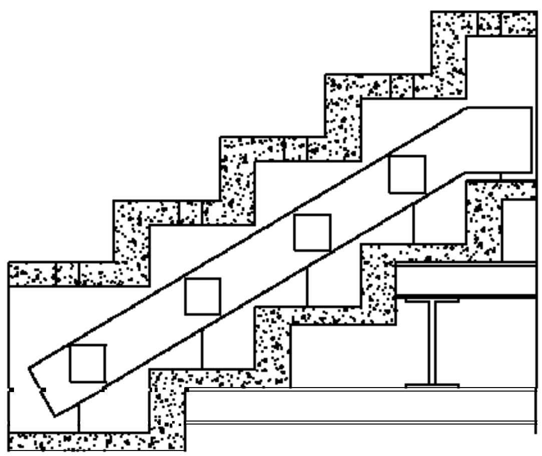
With the use of underfloor air distribution, the ductwork in the gallery catwalk ceiling area is eliminated. There is only one occupied space on gallery (third) level of the theater, the Spot Booth; the same air handler that serves the Proscenium Theater cannot feasibly supply this room. This room is better served off the air-handling unit that supplies the public lobby (AHU-1). In order to supply the Spot Booth, a 740cfm tap is required off the branch duct that runs the length of the second floor circulation hallway. The tap goes up the mechanical shaft in the northeast corner of the balcony.

The underfloor air distribution decreases the load on the cooling coil from 420Mbh to 315Mbh while increasing the airflow from 7,900cfm to 14,200cfm. The increase in airflow results from the increase in the supply air temperature from 55°F to 68°F. The decrease in the load on the cooling coil is a result of the decrease in required outdoor air. The static pressure in the supply air ductwork decreases dramatically in the underfloor air distribution system because for acoustical reasons the flow of the air in the ducts is kept between 200-400 feet per minute. This low air velocity keeps the static pressure on supply air side at 2.5in down from the overhead system that requires 5in of static pressure.

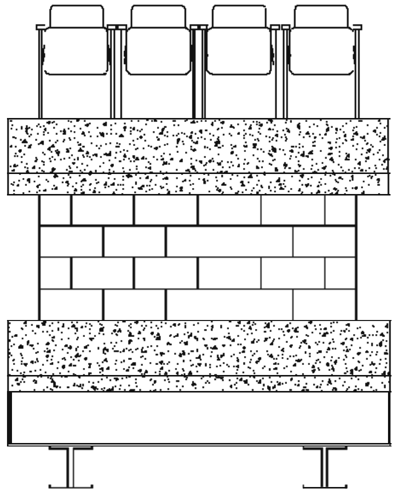
Structural Design

Underfloor Plenum Design:

The implementation of the underfloor air distribution is dependent on there being a plenum under the floor for the area where air needs to be supplied. In order to provide a four foot plenum below the seating area on the first level, the entire foundation for the Proscenium Theater needs to be four feet deeper. Once the present floor plan is depressed four feet, an elevated slab is built. The elevated slab is supported by 10' long rows of grout filled CMU blocks placed approximately 8' apart. The elevated slab will be 12" thick and therefore need a reinforcing in both the top and bottom of the slab. The reinforcing will be #4 bars in each face of the concrete each way.



The balcony will also utilize a four foot plenum for the supply air. The balcony will be raised up four feet in a similar fashion to that of the first level with an elevated slab. The balcony elevated slab will be supported by grout filled CMU blocks. The grout filled CMU blocks will be positioned above lateral supporting I-beams in the balcony. The I-beams that are perpendicular to the seating (main support for the cantilever of the balcony) will increase in size from W12x50 to W16x31. As a result adding the elevated slab to create the plenum the columns that the beams supporting the cantilever connect into will need to be designed to carry a larger load. The elevated slab in the balcony essentially doubles the amount of concrete that the column needs to support. The column will need to be increased from a W10x45 to a W10x60. (Calculations in Appendix F)



The structural support for the balcony is cantilevered steel I-beams connected to columns in the Orchard Street Lobby adjacent to the back of the auditorium. There are also four circular columns supporting the front of the balcony in the Proscenium Theater.

Since the balcony is raised up four feet, the third level of the Proscenium Theater, which contains the Spot Booth, must also be raised up four feet. The third level is only accessible from within the theater so raising the top level of the theater will not affect adjoining the theater to the rest of the building.

Where the theater has access to the rest of the building on the second level the height discrepancy from raising the balcony must be accounted for. There are four entrances to the balcony two are located at the rear of the balcony and then there is one on either side of the stage. The rear entrances will enter the balcony at the middle row level then have the occupants climb several steps to get to their seats on the back two rows. From the side entrances, the occupants will go down a set of steps to get to the first and second rows of seating.

Architectural Theater Considerations:

The addition of the plenum on the balcony increases the height of the Proscenium Theater seating area in the balcony. The increased height of the balcony affects the angle at which the occupants of the balcony view the stage. The architectural standards for theaters limit the viewing angle from the balcony to the arrival point of sight (APS) 2" above the stage to 30˚. The plenum increases the viewing angle from 19˚ to 22˚which is still within the acceptable limits.

The riser height is dependent on the tread length, eye level elevation of the front row and the horizontal distance from the stage. The riser height of the balcony is 20". The required riser height with the underfloor plenum is 16.5". The riser design height is greater the minimum required riser height and therefore provides enough elevation from row to row for the occupants to adequately view the stage. Calculations for the sightline angle and riser height are located in Appendix G.

Acoustical Design

Acoustical Analysis:

The primary factor contributing to the mechanical system design is the use of the spaces and their acoustical sensitivity. The choice of air delivery to the performing spaces plays a significant role in providing patron comfort and determining architectural volume and acoustical response times. Each of the performing spaces must meet the noise criteria specified by the University of Delaware.

The acoustical consultants for the University of Delaware on the Center for the Arts Building classify the Proscenium Theater as a critical space. A critical space must meet background noise levels in the terms of Room Criteria (RC) of RC 18-22 (N). Underfloor supply systems can be extremely effective in controlling background HVAC noise levels. It is recommended to use low-pressure air distribution because noise from high or medium velocity ductwork typically exceeds the required Room Criteria for acoustically critical spaces.

The reverberation times in the Proscenium Theater are higher dependent on shape of the theater as well as the materials. Neither the shape nor the materials in the theater are changing as a result of the implementation of the underfloor air distribution system. Since the original design for the theater was made in accordance with acceptable reverberation times in a theater space, 1.8-2.0s, the underfloor system will not create a variance in this number.

NC and RC Values:

The Trane Acoustical Program (TAP) analyzes the noise levels produced by and attenuated through HVAC equipment. The supply air fan is the component of the air-handling unit that creates the most significant amount of noise that carries through the ductwork to the theater space. The manufacturer of the product specifies the fan sound power levels for the supply air fan.

In TAP, the path of the sound begins at the supply air fan where the custom sound power levels are entered. The ductwork sizes, lengths, and thickness lining affect how the sound and vibrations pass through the ductwork. The sound power level from the diffuser is the last element of HVAC equipment before the air enters the room. TAP calculates the Noise Criteria (NC) and Room Criteria (RC) based on the inputted values.

For the theater, the NC and RC level was determined for the first level and the balcony level. Both the first level and the balcony resulted in NC-16 and RC-17 (N). The output also indicates that there will be no rumble from the low octave band frequencies or hiss from the high octave band frequencies. These levels are below the specified RC 18-22 (N) levels set by the University of Delaware.

Conclusion

The underfloor air distribution system is a viable option for the Proscenium Theater. Underfloor air distribution eliminates supply overhead ductwork in the theater, decreases the required outdoor air, and remains within the acceptable acoustical levels. The biggest feasibility issue with the underfloor system is the structural aspect of the plenum on the balcony. In order to affect the rest of the Center for the Arts building as little as possible the floor-to-floor height from the first to second level was not changed with the addition of the four-foot plenum on the balcony. The entrances to the balcony are all at the level of the middle row of seating and therefore occupants must walk up steps when entering from the back of the balcony and down steps when entering from the front side of the balcony. The structural steel supporting the balcony will need to increase in size in order to carry the additional load of the elevated slab.

There will be a large coordination issue with the placement of the diffusers in the elevated slab. In order to maintain the structural integrity of the elevated slab the holes cored into the slab for the floor diffusers should avoid the rebar as much as possible. Coring the holes after the curing of the concrete will increase cost and labor over leaving holes for the diffusers when pouring the concrete but the placement of the seats could be adversely affected if the holes are placed before the seats.

The underfloor air distribution system decreases the required supply fan horsepower due to a decrease in static pressure and decreases the cooling coil size due to a decrease in the required outdoor air because the air is delivered directly to the occupied breathing zone both of which ultimately result in a decrease of energy consumption.

The supply ductwork in the ceiling catwalk area of the Proscenium Theater is eliminated in the underfloor air distribution system thus leaving ample room for lighting fixtures for the theater performances. The only ductwork that remains in the ceiling catwalk area is the return ducts that collect the return air from the return air shafts in each of the corners of the theater.

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Appendix A: Trace Outputs

Air Handling Unit 2 System Output

Proscenium Theater Loads

- Zone 1 – First level not under the balcony
- Zone 2 – First level under the balcony
- Zone 3 – Balcony
- Zone 4 – Plenum of the Proscenium Theater
- Orchestra Pit

System Checksums
By ae

AHU-2 **Single Zone**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 15
Outside Air: OADB/WB/HR: 89 / 74 / 102

CLG SPACE PEAK

Mo/Hr: 7 / 16
OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	CLG Space Peak: Space Sensible Btu/h	CLG Space Peak: Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0.00	0	0.00
Skylite Cond	0	0	0	0.00	0	0.00
Roof Cond	0	24,095	24,095	3.82	0	0.00
Glass Solar	0	0	0	0.00	0	0.00
Glass Cond	0	0	0	0.00	0	0.00
Wall Cond	0	0	0	0.00	0	0.00
Partition	1,722		1,722	0.27	1,855	1.63
Exposed Floor	0		0	0.00	0	0.00
Infiltration	0		0	0.00	0	0.00
Sub Total ==>	1,722	24,095	25,817	4.09	1,855	1.63
Internal Loads						
Lights	24,154	26,662	50,815	8.05	24,154	21.28
People	143,890		143,890	22.80	84,940	74.83
Misc	4,915	0	4,915	0.78	4,915	4.33
Sub Total ==>	172,958	26,662	199,620	31.63	114,008	100.43
Ceiling Load	-2,895	2,895	0	0.00	-2,348	-2.07
Ventilation Load	0	0	110,088	17.45	0	0.00
Ov/Undr Sizing	0		0	0.00	0	0.00
Exhaust Heat		-3,409	-3,409	-0.54		
Sup. Fan Heat			20,780	3.29		
Ret. Fan Heat		20,780	20,780	3.29		
Duct Heat Pkup		0	257,377	40.79		
Reheat at Design			0	0.00		
Grand Total ==>	171,786	71,022	631,054	100.00	113,515	100.00

HEATING COIL PEAK

Mo/Hr: 13 / 1
OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-22,384	8.44
Glass Solar	0	0	0.00
Glass Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition	-2,168	-2,168	0.82
Exposed Floor	-5,670	-5,670	2.14
Infiltration	0	0	0.00
Sub Total ==>	-7,838	-30,222	11.40
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-1,205	0	0.00
Ventilation Load	0	-138,181	52.13
Ov/Undr Sizing	-100,148	-100,148	37.78
Exhaust Heat		3,474	-1.31
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Grand Total ==>	-109,190	-265,076	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	75.0
Plenum	78.7	66.6
Return	76.5	68.0
Ret/OA	81.5	58.0
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Vent	2,301	2,301
Infil	0	0
Supply	14,027	14,027
MinStop/Rh	0	0
Return	14,027	14,027
Exhaust	2,301	2,301
Rm Exh	0	0
Auxiliary	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	16.4	16.4
cfm/ft²	1.87	1.87
cfm/ton	533.45	
ft²/ton	285.24	
Btu/hr·ft²	42.07	-33.09
No. People	502	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	26.3	315.5	248.9	14,027	81.5	64.6	64.4	50.2	50.1	53.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	26.3	315.5								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	7,500		
Part	1,863		
ExFlr	150		
Roof	6,043	0	0
Wall	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-248.2	14,027	59.1	75.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-248.2			

Room Checksums

By ae

Zone 1 Theater seating UFAD

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 89 / 74 / 102

Clg Space Peak — Mo/Hr: 7 / 16; OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0.00	0	0.00
Skylite Cond	0	0	0	0.00	0	0.00
Roof Cond	0	0	0	0.00	0	0.00
Glass Solar	0	0	0	0.00	0	0.00
Glass Cond	0	0	0	0.00	0	0.00
Wall Cond	0	0	0	0.00	0	0.00
Partition	1,132		1,132	0.53	1,197	2.93
Exposed Floor	0		0	0.00	0	0.00
Infiltration	0		0	0.00	0	0.00
Sub Total ==>	1,132	0	1,132	0.53	1,197	2.93
Internal Loads						
Lights	7,236	0	7,236	3.36	7,236	17.72
People	53,400		53,400	24.80	32,400	79.35
Misc	0	0	0	0.00	0	0.00
Sub Total ==>	60,636	0	60,636	28.16	39,636	97.07
Ceiling Load	0	0	0	0.00	0	0.00
Ventilation Load	0	0	43,073	20.01	0	0.00
Ov/Undr Sizing	0		0	0.00	0	0.00
Exhaust Heat		-1,323	-1,323	-0.61		
Sup. Fan Heat			7,771	3.61		
Ret. Fan Heat		7,771	7,771	3.61		
Duct Heat Pkup		0	96,248	44.70		
Reheat at Design			0	0.00		
Grand Total ==>	61,767	6,448	215,308	100.00	40,832	100.00

HEATING COIL PEAK

Mo/Hr: 13 / 1; OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition	-745	-745	0.79
Exposed Floor	-5,670	-5,670	6.00
Infiltration	0	0	0.00
Sub Total ==>	-6,415	-6,415	6.79
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-53,627	56.77
Ov/Undr Sizing	-34,418	-34,418	36.44
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Grand Total ==>	-40,832	-94,459	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	75.0
Plenum	75.0	68.0
Return	76.3	68.0
Ret/OA	78.5	58.8
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Vent	893	893
Infil	0	0
Supply	5,245	5,245
MinStop/Rh	0	0
Return	5,245	5,245
Exhaust	893	893
Rm Exh	0	0
Auxil	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	17.0	17.0
cfm/ft²	3.09	3.09
cfm/ton	584.69	
ft²/ton	189.50	
Btu/hr·ft²	63.33	-55.56
No. People	200	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	9.0	107.7	82.6	5,245	78.5	63.4	63.4	50.2	50.1	53.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	9.0	107.7								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,700		
Part	640		
ExFlr	150		
Roof	0	0	0
Wall	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-94.5	5,245	58.8	75.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-94.5			

Room Checksums
By ae

Zone 2 UFAD Theater

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 89 / 74 / 102

Clg Space Peak — Mo/Hr: 7 / 16; OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0.00	0	0.00
Skylite Cond	0	0	0	0.00	0	0.00
Roof Cond	0	0	0	0.00	0	0.00
Glass Solar	0	0	0	0.00	0	0.00
Glass Cond	0	0	0	0.00	0	0.00
Wall Cond	0	0	0	0.00	0	0.00
Partition	644		644	0.55	681	2.93
Exposed Floor	0		0	0.00	0	0.00
Infiltration	0		0	0.00	0	0.00
Sub Total ==>	644	0	644	0.55	681	2.93
Internal Loads						
Lights	8,027	0	8,027	6.86	8,027	34.47
People	24,030		24,030	20.53	14,580	62.61
Misc	0	0	0	0.00	0	0.00
Sub Total ==>	32,057	0	32,057	27.38	22,607	97.07
Ceiling Load	0	0	0	0.00	0	0.00
Ventilation Load	0	0	21,246	18.15	0	0.00
Ov/Undr Sizing	0		0	0.00	0	0.00
Exhaust Heat		-637	-637	-0.54		
Sup. Fan Heat			4,432	3.79		
Ret. Fan Heat		4,432	4,432	3.79		
Duct Heat Pkup		0	54,895	46.89		
Reheat at Design			0	0.00		
Grand Total ==>	32,702	3,795	117,069	100.00	23,289	100.00

HEATING COIL PEAK

Mo/Hr: 13 / 1; OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition	-424	-424	0.86
Exposed Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-424	-424	0.86
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-25,823	52.58
Ov/Undr Sizing	-22,865	-22,865	46.56
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Grand Total ==>	-23,289	-49,111	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	75.0
Plenum	75.0	68.0
Return	76.3	68.0
Ret/OA	78.2	60.2
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Vent	430	430
Infil	0	0
Supply	2,992	2,992
MinStop/Rh	0	0
Return	2,992	2,992
Exhaust	430	430
Rm Exh	0	0
Auxil	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	14.4	14.4
cfm/ft²	2.72	2.72
cfm/ton	613.31	
ft²/ton	225.51	
Btu/hr·ft²	53.21	-44.65
No. People	90	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	4.9	58.5	46.5	2,992	78.2	62.7	60.8	50.2	50.1	53.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.9	58.5								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,100		
Part	364		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-49.1	2,992	60.2	75.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-49.1			

Room Checksums
By ae

Zone 3 UFAD Theater

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 89 / 74 / 102
Clg Space Peak — Mo/Hr: 7 / 16; OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0.00	0	0.00
Skylite Cond	0	0	0	0.00	0	0.00
Roof Cond	0	0	0	0.00	0	0.00
Glass Solar	0	0	0	0.00	0	0.00
Glass Cond	0	0	0	0.00	0	0.00
Wall Cond	0	0	0	0.00	0	0.00
Partition	529		529	0.30	559	1.79
Exposed Floor	0		0	0.00	0	0.00
Infiltration	0		0	0.00	0	0.00
Sub Total ==>	529	0	529	0.30	559	1.79
Internal Loads						
Lights	1,570	0	1,570	0.90	1,570	5.02
People	48,060		48,060	27.65	29,160	93.20
Misc	0	0	0	0.00	0	0.00
Sub Total ==>	49,630	0	49,630	28.55	30,730	98.21
Ceiling Load	0	0	0	0.00	0	0.00
Ventilation Load	0	0	39,245	22.58	0	0.00
Ov/Undr Sizing	0		0	0.00	0	0.00
Exhaust Heat		-1,230	-1,230	-0.71		
Sup. Fan Heat			5,955	3.43		
Ret. Fan Heat		5,955	5,955	3.43		
Duct Heat Pkup		0	73,753	42.43		
Reheat at Design			0	0.00		
Grand Total ==>	50,159	4,725	173,836	100.00	31,289	100.00

HEATING COIL PEAK

Mo/Hr: 13 / 1; OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition	-348	-348	0.43
Exposed Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-348	-348	0.43
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-49,843	61.43
Ov/Undr Sizing	-30,941	-30,941	38.14
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Grand Total ==>	-31,289	-81,133	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	75.0
Plenum	75.0	68.0
Return	76.3	68.0
Ret/OA	79.0	56.9
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Vent	830	830
Infil	0	0
Supply	4,019	4,019
MinStop/Rh	0	0
Return	4,019	4,019
Exhaust	830	830
Rm Exh	0	0
Auxil	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	20.7	20.7
cfm/ft²	2.51	2.51
cfm/ton	554.92	
ft²/ton	220.90	
Btu/hr·ft²	54.32	-50.71
No. People	180	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	7.2	86.9	64.3	4,019	79.0	64.1	66.2	50.2	50.1	53.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.2	86.9								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,600		
Part	299		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-81.1	4,019	56.9	75.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-81.1			

Room Checksums
By ae

Zone 4 UFAD Theater

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 89 / 74 / 102
Clg Space Peak — Mo/Hr: 7 / 15; OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0.00	0	0.00
Skylite Cond	0	0	0	0.00	0	0.00
Roof Cond	0	24,095	24,095	32.74	0	0.00
Glass Solar	0	0	0	0.00	0	0.00
Glass Cond	0	0	0	0.00	0	0.00
Wall Cond	0	0	0	0.00	0	0.00
Partition	-582		-582	-0.79	-582	-6.73
Exposed Floor	0		0	0.00	0	0.00
Infiltration	0		0	0.00	0	0.00
Sub Total ==>	-582	24,095	23,512	31.95	-582	-6.73
Internal Loads						
Lights	6,665	26,662	33,327	45.28	6,665	77.06
People	0		0	0.00	0	0.00
Misc	4,915	0	4,915	6.68	4,915	56.82
Sub Total ==>	11,580	26,662	38,242	51.96	11,580	133.88
Ceiling Load	-2,895	2,895	0	0.00	-2,348	-27.15
Ventilation Load	0	0	0	0.00	0	0.00
Ov/Undr Sizing	0		0	0.00	0	0.00
Exhaust Heat		0	0	0.00		
Sup. Fan Heat			823	1.12		
Ret. Fan Heat		823	823	1.12		
Duct Heat Pkup		0	10,194	13.85		
Reheat at Design			0	0.00		
Grand Total ==>	8,103	54,474	73,595	100.00	8,650	100.00

HEATING COIL PEAK

Mo/Hr: 13 / 1; OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-22,384	433.48
Glass Solar	0	0	0.00
Glass Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition	-651	-651	12.61
Exposed Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-651	-23,035	446.09
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-1,205	0	0.00
Ventilation Load	0	0	0.00
Ov/Undr Sizing	-2,469	-2,469	47.82
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		20,340	393.91
Grand Total ==>	-4,325	-5,164	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	75.0
Plenum	78.7	66.6
Return	80.1	66.6
Ret/OA	80.1	66.6
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Vent	0	0
Infil	0	0
Supply	556	556
MinStop/Rh	0	0
Return	556	556
Exhaust	0	0
Rm Exh	0	0
Auxil	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	0.20	0.20
cfm/ton	181.18	
ft²/ton	913.11	
Btu/hr·ft²	13.14	-1.84
No. People	0	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	3.1	36.8	36.8	556	80.1	66.8	77.8	50.2	43.4	31.1
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	3.1	36.8								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	2,800		
Part	559		
ExFlr	0		
Roof	6,043	0	0
Wall	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-5.2	556	66.6	75.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-5.2			

Room Checksums
By ae

Orchestra Pit

COOLING COIL PEAK / CLG SPACE PEAK / HEATING COIL PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 89 / 74 / 102
Clg Space Peak — Mo/Hr: 7 / 15; OADB: 89
Heating Coil Peak — Mo/Hr: 13 / 1; OADB: 14

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0.00	0	0.00
Skylite Cond	0	0	0	0.00	0	0.00
Roof Cond	0	0	0	0.00	0	0.00
Glass Solar	0	0	0	0.00	0	0.00
Glass Cond	0	0	0	0.00	0	0.00
Wall Cond	0	0	0	0.00	0	0.00
Partition	0		0	0.00	0	0.00
Exposed Floor	0		0	0.00	0	0.00
Infiltration	0		0	0.00	0	0.00
Sub Total ==>	0	0	0	0.00	0	0.00
Internal Loads						
Lights	655	0	655	1.28	655	6.93
People	18,400		18,400	35.90	8,800	93.07
Misc	0	0	0	0.00	0	0.00
Sub Total ==>	19,055	0	19,055	37.18	9,455	100.00
Ceiling Load	0	0	0	0.00	0	0.00
Ventilation Load	0	0	6,524	12.73	0	0.00
Ov/Undr Sizing	0		0	0.00	0	0.00
Exhaust Heat		-219	-219	-0.43		
Sup. Fan Heat			1,799	3.51		
Ret. Fan Heat		1,799	1,799	3.51		
Duct Heat Pkup		0	22,288	43.49		
Reheat at Design			0	0.00		
Grand Total ==>	19,055	1,580	51,247	100.00	9,455	100.00

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition	0	0	0.00
Exposed Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	0	0	0.00
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-8,888	48.45
Ov/Undr Sizing	-9,455	-9,455	51.55
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Grand Total ==>	-9,455	-18,343	100.00

TEMPERATURES

	Cooling	Heating
SADB	68.0	75.0
Plenum	75.0	68.0
Return	76.3	68.0
Ret/OA	77.9	61.4
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.9	0.0

AIRFLOWS

	Cooling	Heating
Vent	148	148
Infil	0	0
Supply	1,215	1,215
MinStop/Rh	0	0
Return	1,215	1,215
Exhaust	148	148
Rm Exh	0	0
Auxil	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	12.2	12.2
cfm/ft²	4.05	4.05
cfm/ton	568.83	
ft²/ton	140.50	
Btu/hr·ft²	85.41	-61.14
No. People	32	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	2.1	25.6	18.7	1,215	77.9	63.8	66.4	50.2	50.1	53.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.1	25.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	300		
Part	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-18.3	1,215	61.4	75.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-18.3			

Appendix B: ASHRAE Standard 62.1-2004

Room Number	Room Name	Space Description	Area (Sq. Ft)	Occupancy	CFM/ person	CFM/ ft2	RpPz	RaAz	Zone Outdoor Airflow	Zone Primary Airflow	Zone Minimum Airflow	Primary OA Fraction
155	Proscenium Theatre Seating	Auditorium Seating	4,387	502	5	0.06	2510	263	2773	7,900	7900	0.35
155	Proscenium Theatre Seating	Auditorium Seating Redesign	4,387	502	5	0.06	2510	263	2311	14,200	14200	0.16

	Original Design	Redesign
AHU-2 Total Air Flow	7900	14200
V_{ou}	2,773	2,773
E_v	0.80	0.90
V_{ot}	3467	3081
Max Z_p	0.35	0.16
Min OA %	0.44	0.22

Appendix C: Diffuser Specifications

Nailor Industries Inc.

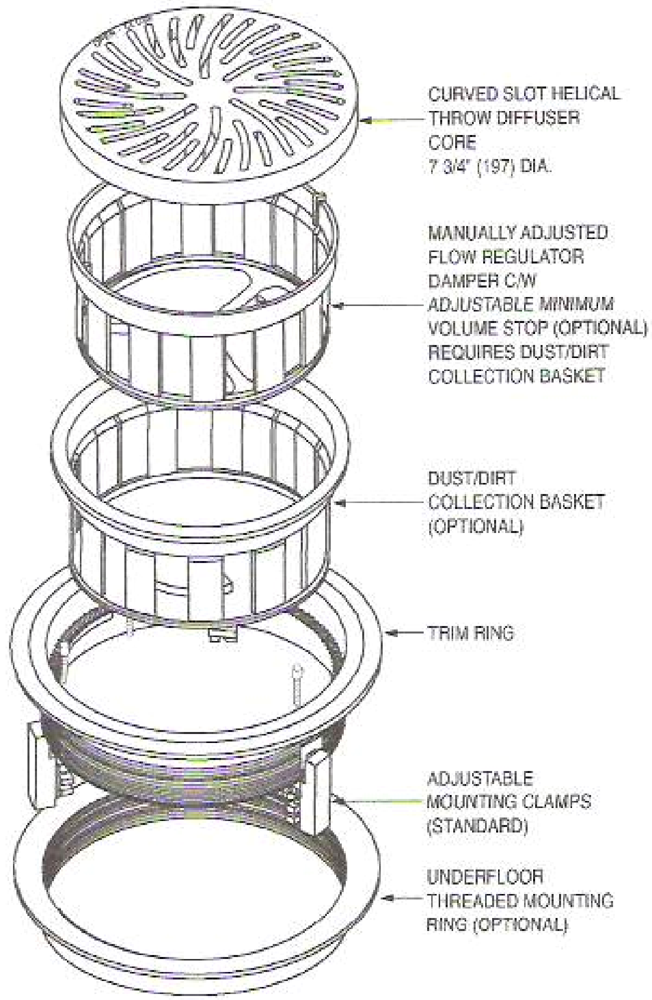
Floor Swirl Diffuser
Round Fixed Discharge Pattern
Model NFD

Nailor Industries Inc.

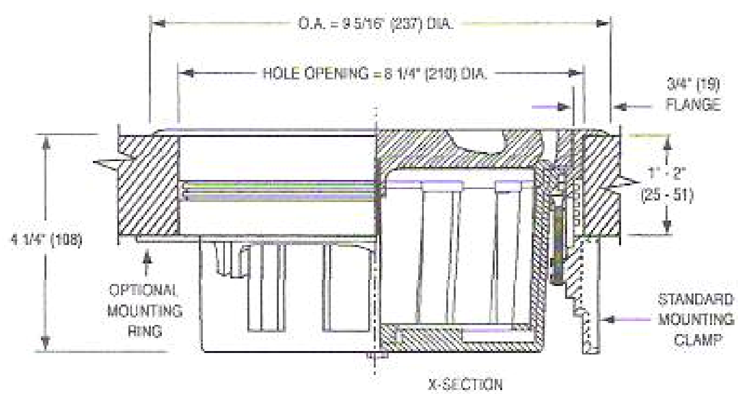
FLOOR "SWIRL" DIFFUSER
FIXED DISCHARGE PATTERN • ROUND
UNDERFLOOR AIR DISTRIBUTION SYSTEMS
MODEL: NFD

DESCRIPTION:
The Nailor NFD floor diffuser is designed for use in raised access floor air distribution systems, where the floor cavity is used as a pressurized supply air plenum. The NFD core design produces a high velocity helical "swirl" discharge air pattern. This design achieves high induction rates of room air which optimizes mixing for maximum comfort conditions.

FEATURES:
- Constructed of high impact polycarbonate plastic complying with UL Standard 94-5V for flammability.
- Nominal size 8" (203) dia. Low profile design.
- Dust/dirt collection basket catches anything that might fall through diffuser face. Removable for cleaning.
- *Optional flow regulator damper adjustable without removing the diffuser core, features visual open/ closed indication and includes built in end stops.*
- Adjustable minimum volume stop.
- *Low pressure drop core/damper assembly design.*
- Architecturally pleasing face design compliments contemporary decor. Lies flush with trim ring flange, with or without damper.
- Rugged trim ring design secures carpet and prevents edges from fraying.
- Unique adjustable mounting clamp design adapts to any floor panel thickness and provides simple and secure installation. Permits installation from above the floor without removal of the floor panel or carpet.
- Optional underfloor mounting ring available.
- Standard finish is GR Gray or BK Black core and trim ring. Damper/basket are black.



SELECTION:
1. ☐ TR Trim Ring (standard)
   ☐ None
2. Dirt Basket/Damper
   ☐ BDA Attached to Core (standard)
   ☐ BDL Loose
   ☐ BOO Basket Only
   ☐ None
3. Mounting (requires trim ring):
   ☐ MC Mounting Clamps (standard)
   ☐ MR Mounting Ring (option)
4. Finish:
   ☐ GR Gray
   ☐ BK Black
   ☐ SP Special (custom color by architect)
   Specify ____________.



Dimensions are in inches (mm).

SCHEDULE TYPE:				
PROJECT:				
ENGINEER:	DATE	B SERIES	SUPERSEDES	DRAWING NO.
CONTRACTOR:	9 - 26 - 03	NFD	5 - 29 - 03	NFD-1

Nailor Industries Inc.

FLOOR "SWIRL" DIFFUSERS
FIXED DISCHARGE PATTERN • ROUND
UNDERFLOOR AIR DISTRIBUTION SYSTEMS
MODELS: NFD, NFD-VAV

Performance Data

Airflow, cfm	30	40	50	60	70	80	90	100	110	120
Plenum Pressure	0.012	0.020	0.029	0.040	0.050	0.063	0.077	0.093	0.108	0.125
Vertical Projection, ft. @ 150, 100, 50 fpm	0.1-0.5-1.2	0.4-1.0-2.0	0.8-1.8-2.8	1.2-2.6-3.5	1.6-3.4-4.2	2.2-4.1-4.8	3.1-4.6-5.3	3.9-5.1-5.8	4.6-5.5-6.2	5.2-5.8-6.6
Horizontal Spread, ft. @ 150, 100, 50 fpm	1.0-1.0-1.5	1.0-1.0-2.0	1.5-1.8-2.7	1.7-2.9-4.1	1.9-4.0-5.5	2.1-4.1-5.8	2.5-3.9-5.7	2.9-3.8-5.5	3.1-3.7-5.4	3.3-3.6-5.3
NC	–	–	–	–	–	–	–	15	18	20

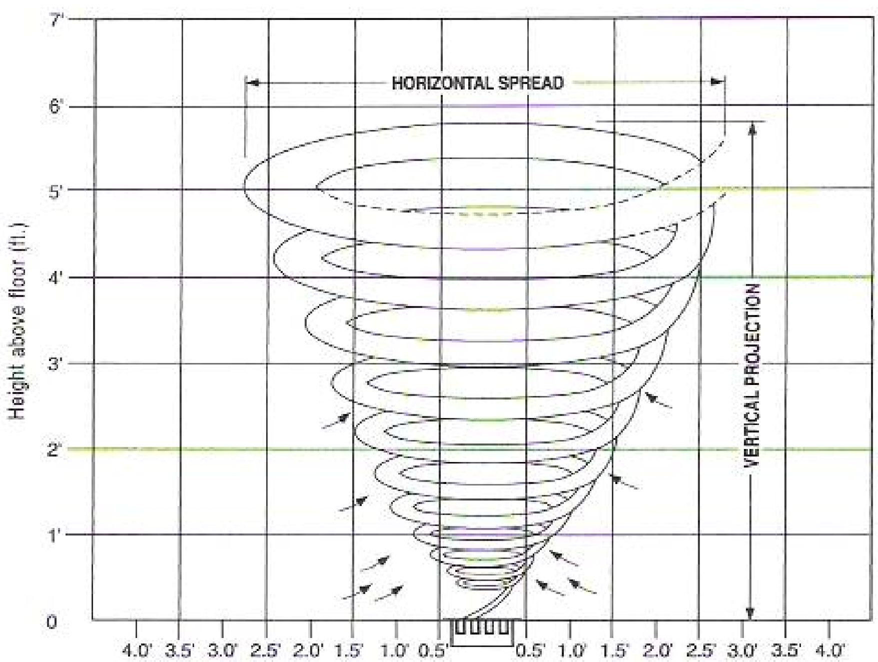
Correction Factor for Return Air Applications: Multiply Plenum Pressure by x 2.65 to determine static pressure drop.

Correction Factors for other supply air temperature differentials.

ΔT (°F)	-6	-8	-10	-12	-14	-16
Projection, ft.	x 1.33	x 1.11	x 1.00	x 0.96	x 0.92	x 0.91
Spread, ft.	x 0.87	x 0.94	x 1.00	x 1.06	x 1.11	x 1.16

Performance Notes:

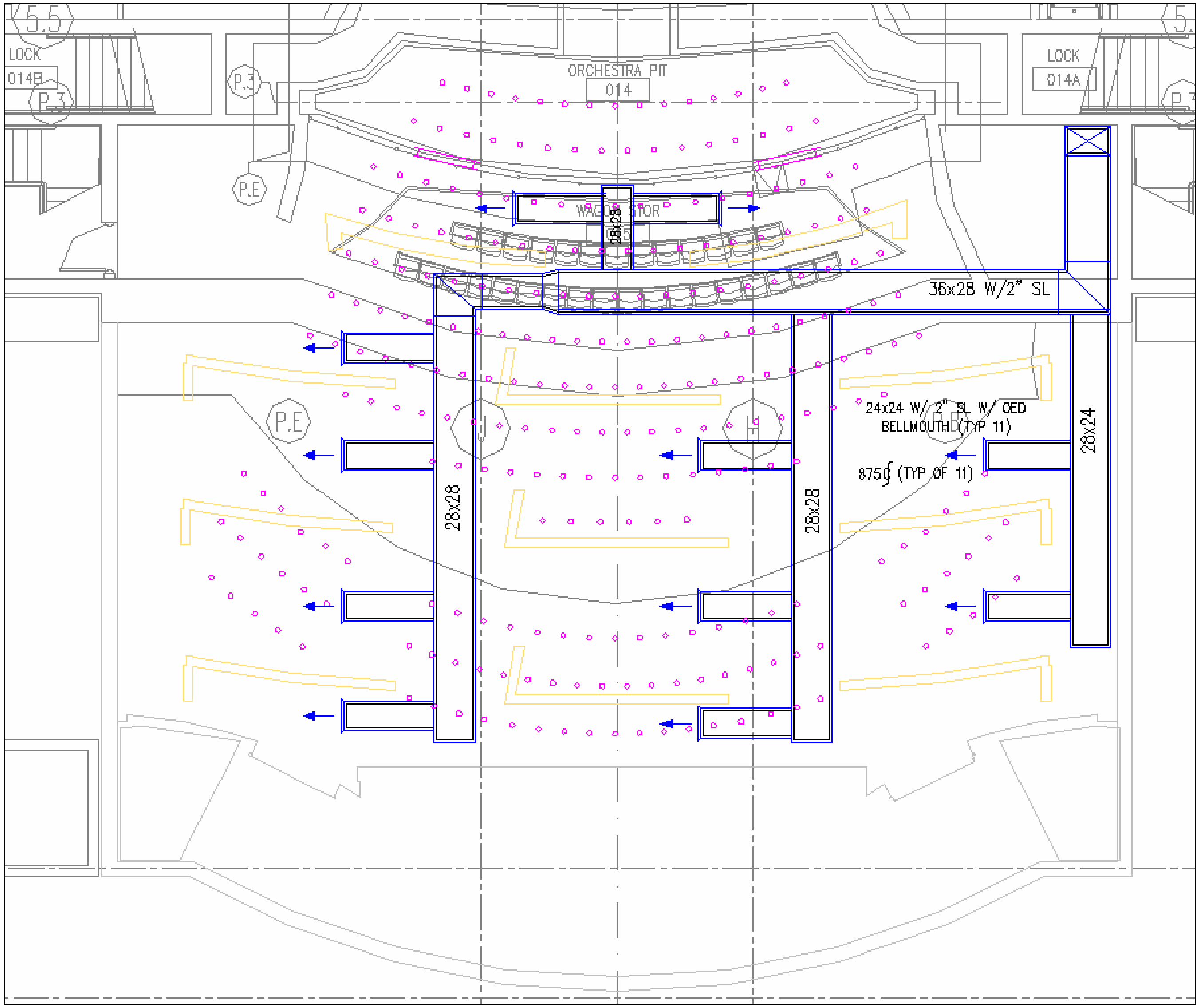
1. Projection and Spread data were determined in a room with a 11' ceiling height and 10°F ΔT, between supply air and averaged occupied room temperature.
2. Vertical projection (throw) is the maximum height above the floor where terminal velocities of 150, 100 and 50 fpm were observed. Horizontal Spread is the total width of the isovel where terminal velocities of 150, 100 and 50 fpm were observed.
3. Noise Criteria (values) based on 10 dB room absorption, re 10^{-12} watts. Dash (-) in space denotes an NC value of less than 15.
4. Pressure is in inches w.g..
5. Tests conducted with dirt basket/damper installed. Damper fully open. Ak = 0.104
6. Data derived from independent tests conducted in accordance with ANSI/ASHRAE Standard 70 – 1991.



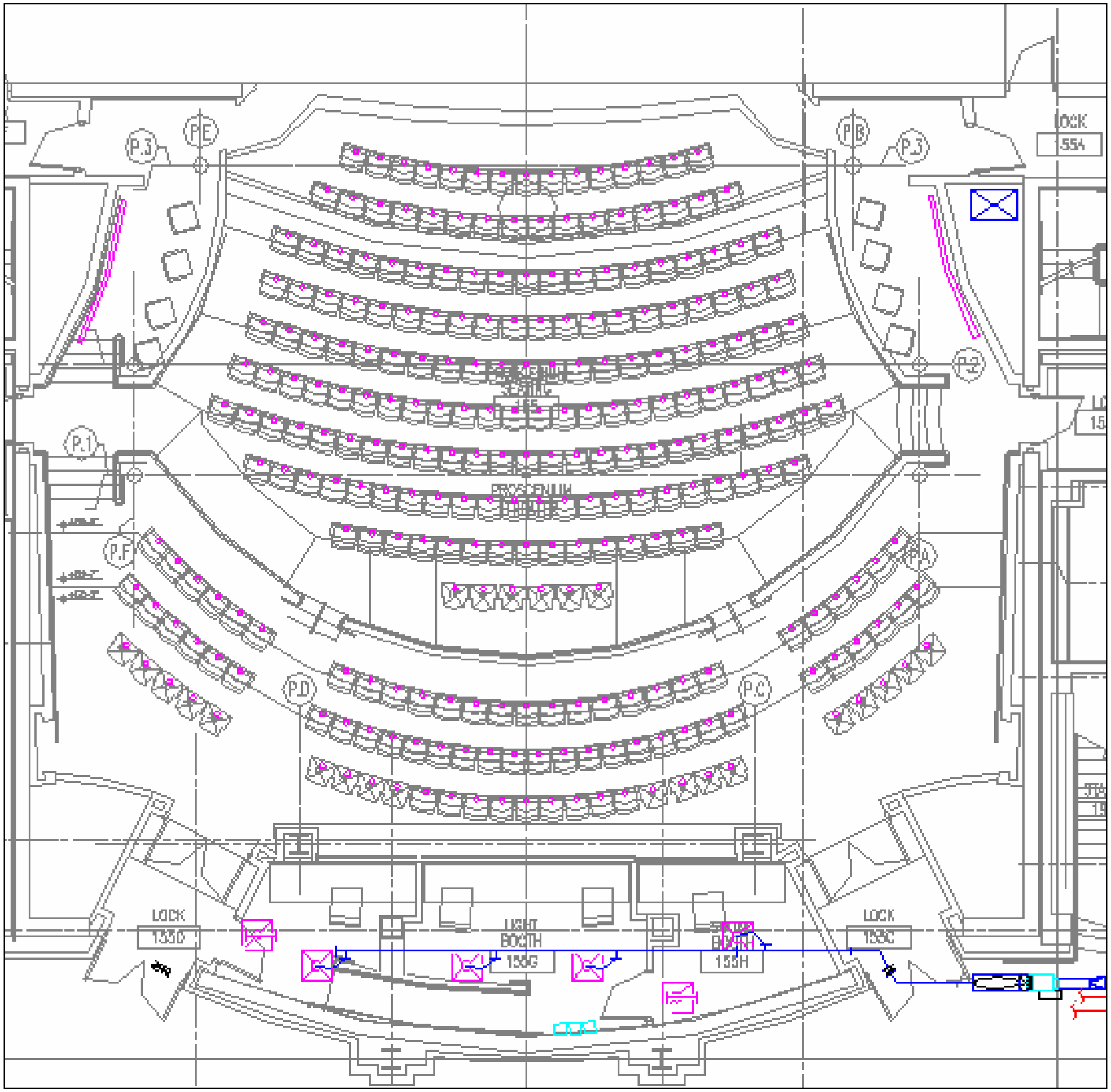
High induction "Swirl" Pattern. 100 cfm supply @10°F ΔT. Outline indicates maximum room air velocity of 50 fpm.

SCHEDULE TYPE	Dimensions are in inches (mm).			
PROJECT				
ENGINEER	DATE	B SERIES	SUPERSEDES	DRAWING NO.
CONTRACTOR	2 - 26 - 04	NFD	9 - 5 - 02	NFD-2

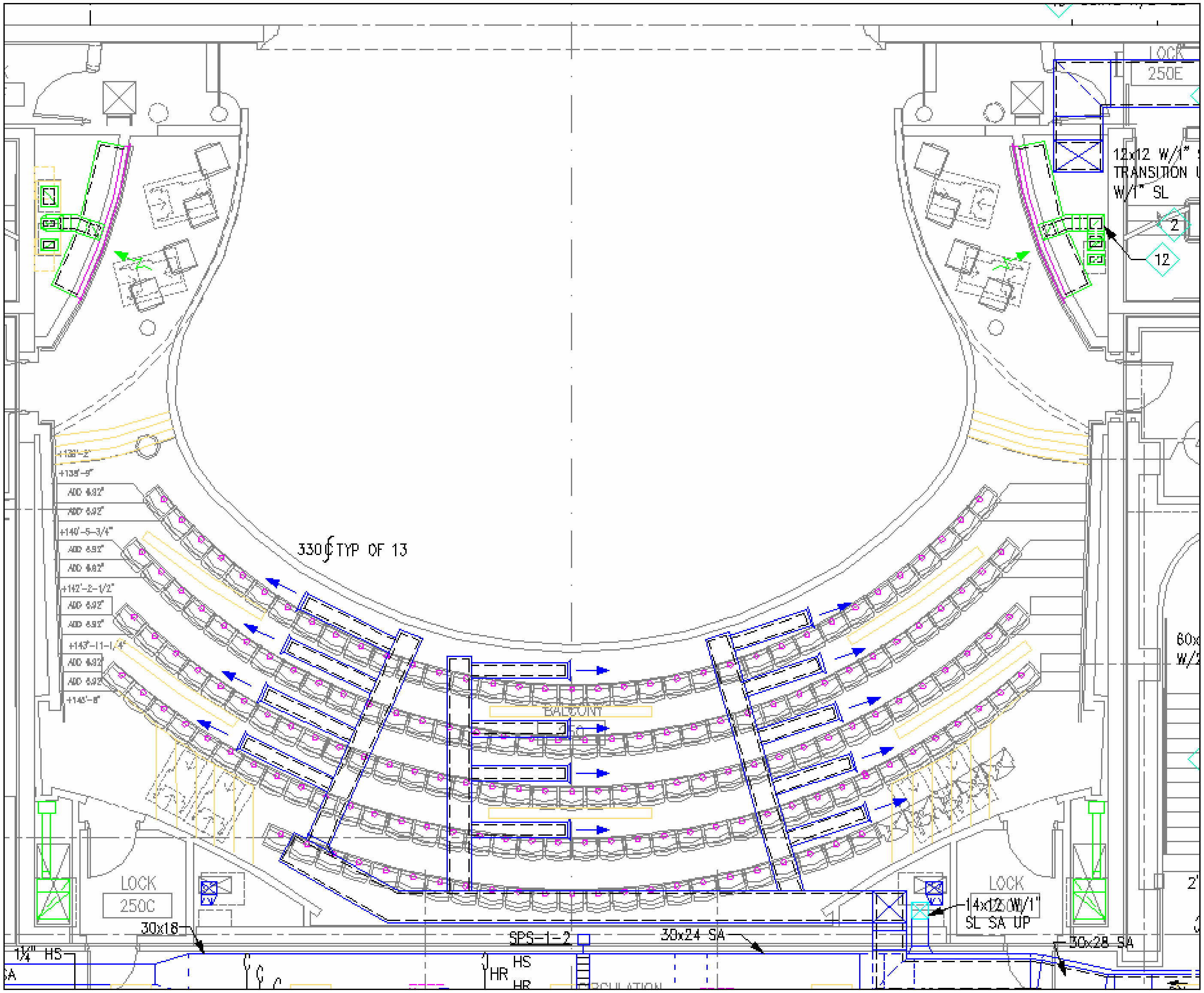
Appendix D: Proscenium Theater Mechanical Plans



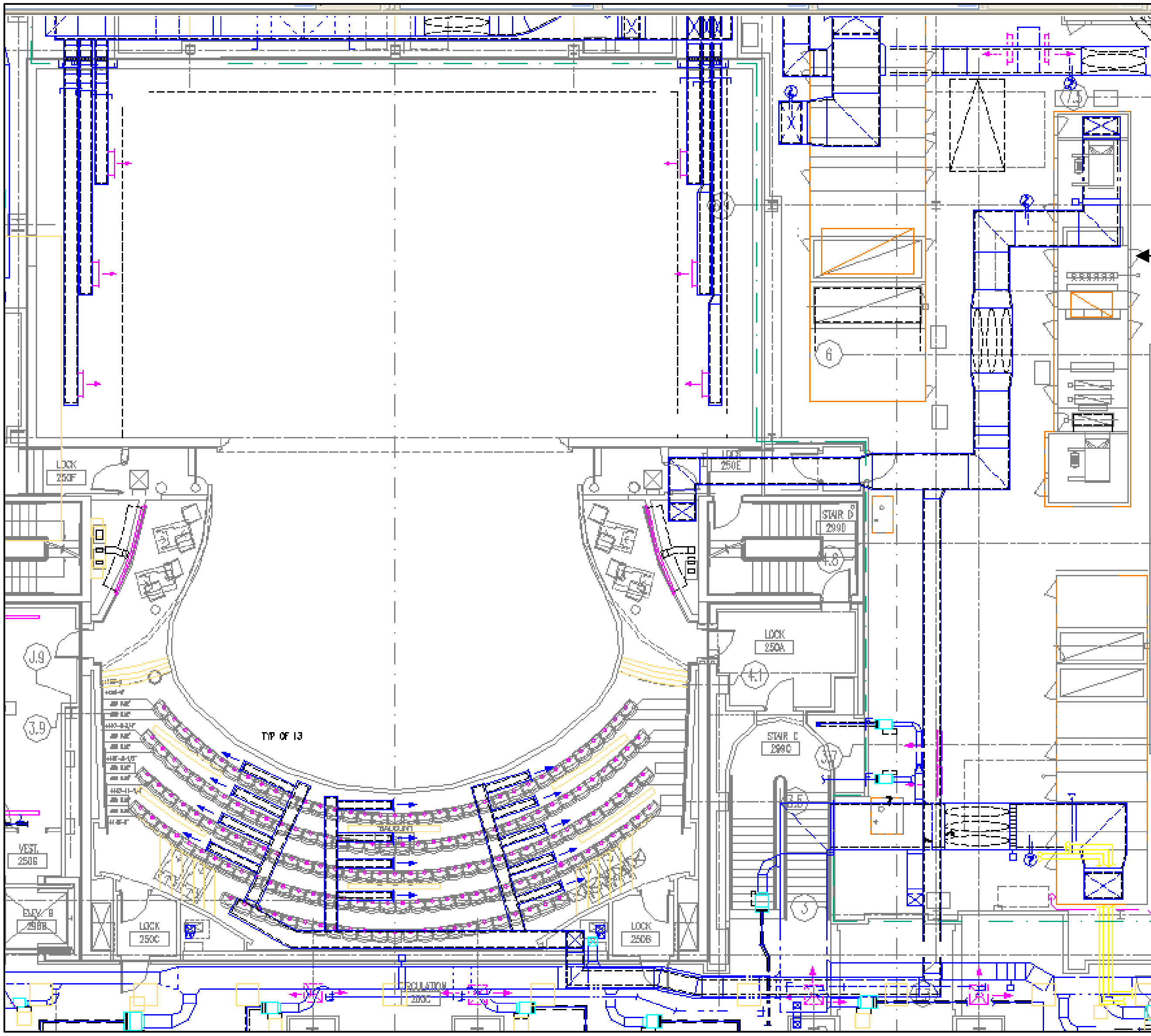
Basement level
Mechanical plan



First level
Mechanical plan



Second level (Balcony) Mechanical plan



Air Handling Unit 2 that serves the Proscenium Theater

Appendix E: Rebar Calculations

Assuming fixed on both ends.

Load: $w_u = 1.2D + 1.6L$

End moment for fixed-fixed beam: $M_u = \frac{wl^2}{12}$

Middle Moment for fixed-fixed beam: $M_u = \frac{wl^2}{24}$

$$\phi M_n = \phi A_s F_y (d - \frac{a}{2}) > M_u$$

$$a = \frac{A_s F_y}{0.85 f_c' b}$$
$$\phi = 0.90$$
$$F_y = 60ksi$$
$$f_c' = 4ksi$$
$$b = 12in$$
$$d = 11in$$

Assume dead load of 150psf for weight of concrete and 60psf for seating. Assume live Load of 100psf.

$$w_u = 412 psf$$
$$End\ M_u = 3435 ft \cdot lb$$
$$A_s = 0.069 \, {in^2}/{ft} \ rebar$$
$$Middle\ M_u = 1716 ft \cdot lb$$
$$A_s = 0.0347 \, {in^2}/{ft} \ rebar$$

For shrinkage and temperature: $0.0018(144in^2) = 0.26in^2 \Rightarrow use\ \#5\ rebar$

Because of the thickness of the slab (slab > 10”) the rebar should be put in the top and bottom of the slab, therefore use #4 rebar in each face both directions.

Appendix F: Steel Calculations

Beams

Dead load – assume 150psf for concrete and 60psf for fixed seating

$Slab = 18.8kip$

$Seating = 4.3kip$

Live Load – assume 100psf

$7.2kip$

$w = 1.2(23.1) + 1.6(7.2)$

$w = 39.3kip$

$M = 39.3kip \times 5'$

$M = 196.3\, ft \cdot kip$

From the Beam Design Moments graph in AISC: W16x31

Columns

Unbraced length = 24’

Table 4.2 in AISC:

Original column W10x45 can carry 138kip

Elevated slab doubles the amount of concrete column will need to carry twice as much

W10x60 can carry 280kip

Appendix G: Theater Calculations

Balcony Sightline Angle
Maximum angle 30˚
Horizontal length from APS to back row of balcony = 58’
Vertical distance from APS to eye level = 24’
Balcony sightline angle = 22˚

Riser Height

$$R = \frac{T}{D_B}\left[E_B + (N-1)C\right] + C$$

$T = 3\,ft\ (row\ to\ row\ spacing)$

$D_B = 46.5\,ft\ (horizontal\ distance\ from\ APS\ to\ eye\ position\ at\ front\ row\ of\ balcony)$

$E_B = 16.5\,ft\ (elevation\ of\ eye\ level\ at\ front\ row\ of\ balcony\ above\ APS)$

$N = 5\ (number\ of\ rows)$

$C = 5in\ (sightline\ head\ clearance)$

$R = 1.37\,ft$

Appendix H: TAP Outputs

Octave Band Data - Supply air fan to first level seating area
Octave Band Data - Supply air fan to balcony level seating area
NC Curve - First level seating area
NC Curve – Balcony level seating area
RC Curve - First level seating area
RC Curve - Balcony level seating area

THE TRANE ACOUSTICS PROGRAM

Project Name: Center For the Arts
Location: Newark, DE
Building Owner: University of Delaware
Project Number:
Comments:

Path Table View -- Path2:

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
Custom Element	**95**	**93**	**89**	**89**	**87**	**83**	**78**	Supply air fan AHU 2
Sound Plenum	**-10**	**-14**	**-14**	**1**	**1**	**1**	**-1**	
Straight Duct(RL)	**0**	**-1**	**-2**	**-5**	**-4**	**-4**	**-4**	
Elbow (ln.sq.rct)	**0**	**-1**	**-6**	**-11**	**-10**	**-10**	**-10**	
SubSum	85	77	67	74	74	70	63	
	61	**55**	**49**	**40**	**32**	**23**	**13**	Regenerated sound from elbow.
SubSum	85	77	67	74	74	70	63	
Straight Duct(RL)	**-1**	**-2**	**-5**	**-16**	**-13**	**-11**	**-11**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	83	71	55	51	54	52	45	
	72	**72**	**70**	**65**	**57**	**46**	**30**	Regenerated sound from elbow.
SubSum	83	75	70	65	59	53	45	
Straight Duct(RL)	**-2**	**-2**	**-6**	**-18**	**-15**	**-13**	**-12**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	80	69	57	40	37	33	26	
	72	**72**	**70**	**65**	**57**	**46**	**30**	Regenerated sound from elbow.
SubSum	81	74	70	65	57	46	31	
Straight Duct(RL)	**-1**	**-2**	**-5**	**-16**	**-13**	**-11**	**-11**	
Custom Element	**-7**	**-13**	**-24**	**-27**	**-30**	**-21**	**-17**	Sound Attenuator 2-1
Straight Duct(RL)	**-2**	**-2**	**-3**	**-10**	**-18**	**-14**	**-14**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	70	53	31	5	5	5	5	

THE TRANE ACOUSTICS PROGRAM

Project Name: Center For the Arts
Project Number:

Path Table View -- Path2:

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
				Octave Band Data				
	72	**72**	**70**	**65**	**57**	**46**	**30**	Regenerated sound from elbow.
SubSum	74	72	70	65	57	46	30	
Junction (90,atten.)ABR	**-2**	**-2**	**-2**	**-2**	**-2**	**-2**	**-2**	
SubSum	72	70	68	63	55	44	28	
	61	**56**	**50**	**44**	**36**	**28**	**18**	Regenerated sound from junction.
SubSum	72	70	68	63	55	44	28	
Straight Duct(RL)	**-6**	**-6**	**-12**	**-35**	**-40**	**-40**	**-40**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	65	60	49	21	8	5	5	
	66	**66**	**63**	**58**	**50**	**38**	**22**	Regenerated sound from elbow.
SubSum	69	67	63	58	50	38	22	
Straight Duct(RL)	**-1**	**-1**	**-1**	**-4**	**-7**	**-6**	**-6**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	67	62	55	47	36	25	9	
	66	**66**	**63**	**58**	**50**	**38**	**22**	Regenerated sound from elbow.
SubSum	70	67	64	58	50	38	22	
Straight Duct(RL)	**-8**	**-8**	**-17**	**-40**	**-40**	**-40**	**-40**	
Elbow (ln.sq.rct)	**0**	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	
SubSum	62	58	43	11	5	5	5	
	64	**64**	**61**	**56**	**48**	**36**	**20**	Regenerated sound from elbow.
SubSum	66	65	61	56	48	36	20	
Straight Duct(RL)	**-2**	**-3**	**-8**	**-25**	**-22**	**-18**	**-17**	
Junction (T,atten.)	**-3**	**-3**	**-2**	**-2**	**-2**	**-2**	**-2**	
SubSum	61	59	51	29	24	16	5	
	54	**48**	**43**	**35**	**27**	**18**	**8**	Regenerated sound from junction.
SubSum	62	59	52	36	29	20	10	
Straight Duct(RL)	**-4**	**-6**	**-15**	**-40**	**-40**	**-34**	**-32**	
SubSum	58	53	37	5	5	5	5	
Junction (90,regen)	**49**	**44**	**37**	**29**	**22**	**12**	**2**	
SubSum	59	54	40	29	22	13	7	
Straight Duct(RL)	**-3**	**-4**	**-10**	**-30**	**-26**	**-22**	**-20**	
Junction (90,atten.)ABR	**-3**	**-3**	**-3**	**-3**	**-3**	**-3**	**-3**	
SubSum	53	47	27	5	5	5	5	

THE TRANE ACOUSTICS PROGRAM

Project Name: Center For the Arts
Project Number:

Path Table View -- Path2:

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
	27	**22**	**16**	**9**	**2**	**0**	**0**	Regenerated sound from junction.
SubSum	53	47	27	10	7	6	6	
Straight Duct(RL)	**-3**	**-4**	**-10**	**-29**	**-26**	**-22**	**-20**	
SubSum	50	43	17	5	5	5	5	
Elbow (RctVanes)	**56**	**55**	**51**	**44**	**34**	**20**	**3**	
SubSum	57	55	51	44	34	20	7	
Straight Duct(RL)	**-1**	**-1**	**-3**	**-9**	**-8**	**-7**	**-6**	
Junction (90,atten.)ABR	**-3**	**-3**	**-2**	**-2**	**-2**	**-2**	**-2**	
SubSum	53	51	46	33	24	11	5	
	21	**15**	**10**	**3**	**0**	**0**	**0**	Regenerated sound from junction.
SubSum	53	51	46	33	24	11	6	
Straight Duct(RL)	**-2**	**-3**	**-8**	**-23**	**-21**	**-17**	**-16**	
Junction (90,atten.)ABR	**-3**	**-3**	**-2**	**-2**	**-2**	**-2**	**-2**	
SubSum	48	45	36	8	5	5	5	
	13	**7**	**0**	**0**	**0**	**0**	**0**	Regenerated sound from junction.
SubSum	48	45	36	9	6	6	6	
Straight Duct(RL)	**-3**	**-3**	**-9**	**-26**	**-23**	**-20**	**-18**	
Junction (90,atten.)ABR	**-3**	**-3**	**-2**	**-2**	**-2**	**-2**	**-2**	
SubSum	42	39	25	5	5	5	5	
	3	**0**	**0**	**0**	**0**	**0**	**0**	Regenerated sound from junction.
SubSum	42	39	25	6	6	6	6	
Straight Duct(RL)	**-2**	**-3**	**-8**	**-23**	**-21**	**-17**	**-16**	
Junction (90,atten.)ABR	**-4**	**-4**	**-4**	**-4**	**-4**	**-4**	**-4**	
SubSum	36	32	13	5	5	5	5	
	0	**0**	**0**	**0**	**0**	**0**	**0**	Regenerated sound from junction.
SubSum	36	32	13	6	6	6	6	
Straight Duct(RL)	**-2**	**-3**	**-7**	**-19**	**-17**	**-15**	**-13**	
Sound Plenum	**-16**	**-18**	**-18**	**-20**	**-20**	**-20**	**-21**	
SubSum	18	11	5	5	5	5	5	
Custom Element	**0**	**37**	**28**	**27**	**27**	**23**	**15**	Floor diffuser
SubSum	18	37	28	27	27	23	15	
Indoor (Diffuse)	**-9**	**-9**	**-9**	**-9**	**-9**	**-9**	**-9**	

THE TRANE ACOUSTICS PROGRAM

Project Name: Center For the Arts
Project Number:

Path Table View -- Path2:

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
				Octave Band Data				
SUM	9	28	19	18	18	14	6	
RATINGS	NC 16			RC 17(N)		22 dBA		

THE TRANE ACOUSTICS PROGRAM

Project Name: Center For the Arts
Location: Newark, DE
Building Owner: University of Delaware
Project Number:
Comments:

Path Table View -- Path1:

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
Custom Element	**95**	**93**	**89**	**89**	**87**	**83**	**78**	Supply air fan AHU 2
Sound Plenum	**-10**	**-14**	**-14**	**0**	**0**	**0**	**-2**	
Straight Duct(RL)	**-1**	**-1**	**-2**	**-5**	**-5**	**-4**	**-4**	
Elbow (ln.sq.rct)	**0**	**-1**	**-6**	**-11**	**-10**	**-10**	**-10**	
SubSum	84	77	67	73	72	69	62	
	67	**61**	**54**	**47**	**38**	**30**	**19**	Regenerated sound from elbow.
SubSum	84	77	67	73	72	69	62	
Straight Duct(RL)	**-2**	**-2**	**-5**	**-16**	**-14**	**-12**	**-11**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	81	71	55	50	51	50	44	
	75	**75**	**74**	**70**	**63**	**52**	**38**	Regenerated sound from elbow.
SubSum	82	76	74	70	63	54	45	
Straight Duct(RL)	**-2**	**-2**	**-6**	**-19**	**-17**	**-14**	**-13**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	79	70	61	44	39	33	25	
	75	**75**	**74**	**70**	**63**	**52**	**38**	Regenerated sound from elbow.
SubSum	80	76	74	70	63	52	38	
Straight Duct(RL)	**-2**	**-2**	**-5**	**-16**	**-14**	**-12**	**-11**	
Custom Element	**-7**	**-13**	**-24**	**-27**	**-30**	**-21**	**-17**	Sound Attenuator 2-1
Straight Duct(RL)	**-2**	**-2**	**-4**	**-11**	**-19**	**-16**	**-15**	
Elbow (ln.sq.rct)	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	**-7**	
SubSum	68	55	34	9	5	5	5	

THE TRANE ACOUSTICS PROGRAM

Project Name: Center For the Arts
Project Number:

Karen Schulte
Mechanical Option

Path Table View -- Path1:

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
	75	**75**	**74**	**70**	**63**	**52**	**38**	Regenerated sound from elbow.
SubSum	76	75	74	70	63	52	38	
Junction (90,atten.)ABR	**-4**	**-4**	**-4**	**-4**	**-4**	**-4**	**-4**	
SubSum	72	71	70	66	59	48	34	
	59	**55**	**49**	**43**	**35**	**28**	**19**	Regenerated sound from junction.
SubSum	72	71	70	66	59	48	34	
Straight Duct(RL)	**-17**	**-18**	**-33**	**-40**	**-40**	**-40**	**-40**	
Elbow (ln.sq.rct)	**0**	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	
SubSum	55	52	33	19	12	5	5	
	61	**61**	**60**	**56**	**49**	**39**	**25**	Regenerated sound from elbow.
SubSum	62	62	60	56	49	39	25	
Straight Duct(RL)	**-12**	**-13**	**-23**	**-40**	**-40**	**-40**	**-40**	
Elbow (ln.sq.rct)	**0**	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	
SubSum	50	48	33	9	5	5	5	
	61	**61**	**60**	**56**	**49**	**39**	**25**	Regenerated sound from elbow.
SubSum	61	61	60	56	49	39	25	
Straight Duct(RL)	**-1**	**-1**	**-2**	**-5**	**-9**	**-8**	**-7**	
Elbow (ln.sq.rct)	**0**	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	
SubSum	60	59	54	44	33	24	11	
	61	**61**	**60**	**56**	**49**	**39**	**25**	Regenerated sound from elbow.
SubSum	64	63	61	56	49	39	25	
Straight Duct(RL)	**-2**	**-2**	**-4**	**-10**	**-19**	**-16**	**-13**	
Elbow (ln.sq.rct)	**0**	**-1**	**-4**	**-7**	**-7**	**-7**	**-7**	
SubSum	62	60	53	39	23	16	5	
	61	**61**	**60**	**56**	**49**	**39**	**25**	Regenerated sound from elbow.
SubSum	65	64	61	56	49	39	25	
Straight Duct(RL)	**-2**	**-2**	**-4**	**-10**	**-19**	**-16**	**-13**	
SubSum	63	62	57	46	30	23	12	
Junction (90,regen)	**52**	**47**	**42**	**35**	**29**	**20**	**12**	
SubSum	63	62	57	46	33	25	15	
Straight Duct(RL)	**-3**	**-4**	**-6**	**-16**	**-31**	**-27**	**-22**	
Junction (90,atten.)ABR	**-3**	**-3**	**-3**	**-3**	**-3**	**-3**	**-3**	
SubSum	57	55	48	27	5	5	5	

THE TRANE ACOUSTICS PROGRAM

Project Name: Center For the Arts
Project Number:

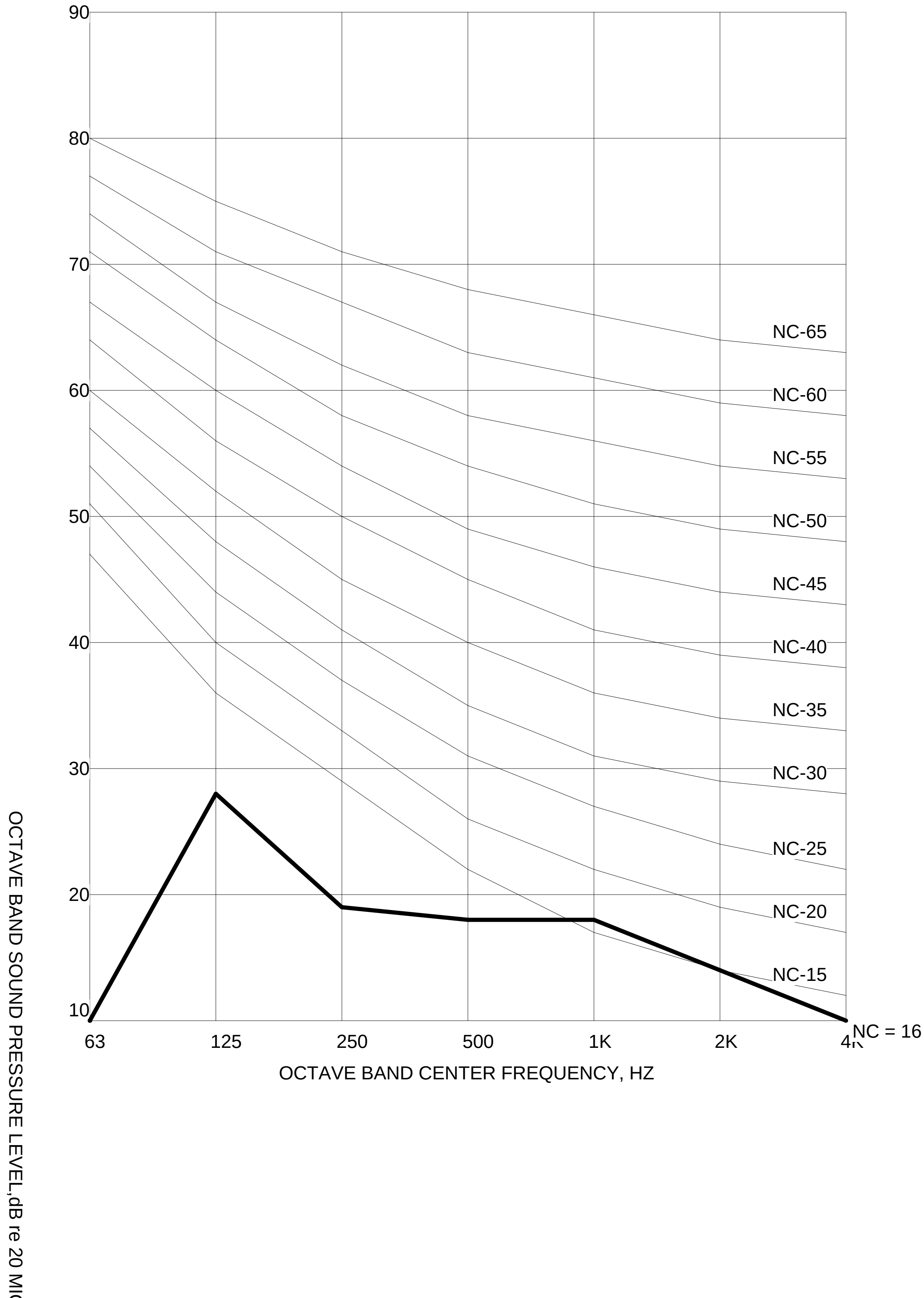
Path Table View -- Path1:

LINE ELEMENT	63	125	250	500	1k	2k	4k	COMMENTS
	37	**32**	**26**	**19**	**10**	**2**	**0**	Regenerated sound from junction.
SubSum	57	55	48	28	11	7	6	
Straight Duct(RL)	**-7**	**-7**	**-11**	**-26**	**-40**	**-40**	**-36**	
SubSum	50	48	37	5	5	5	5	
Elbow (RctVanes)	**61**	**61**	**57**	**51**	**42**	**29**	**13**	
SubSum	61	61	57	51	42	29	14	
Straight Duct(RL)	**-1**	**-1**	**-3**	**-8**	**-14**	**-11**	**-11**	
Sound Plenum	**-18**	**-18**	**-18**	**-20**	**-20**	**-20**	**-21**	
SubSum	42	42	36	23	8	5	5	
Custom Element	**0**	**37**	**28**	**27**	**27**	**23**	**15**	Floor diffuser
SubSum	42	43	37	28	27	23	15	
Indoor (Diffuse)	**-9**	**-9**	**-9**	**-9**	**-9**	**-9**	**-9**	
SUM	33	34	28	19	18	14	6	
RATINGS	NC 16			RC 17(N)		25 dBA		

Trane Acoustics Program

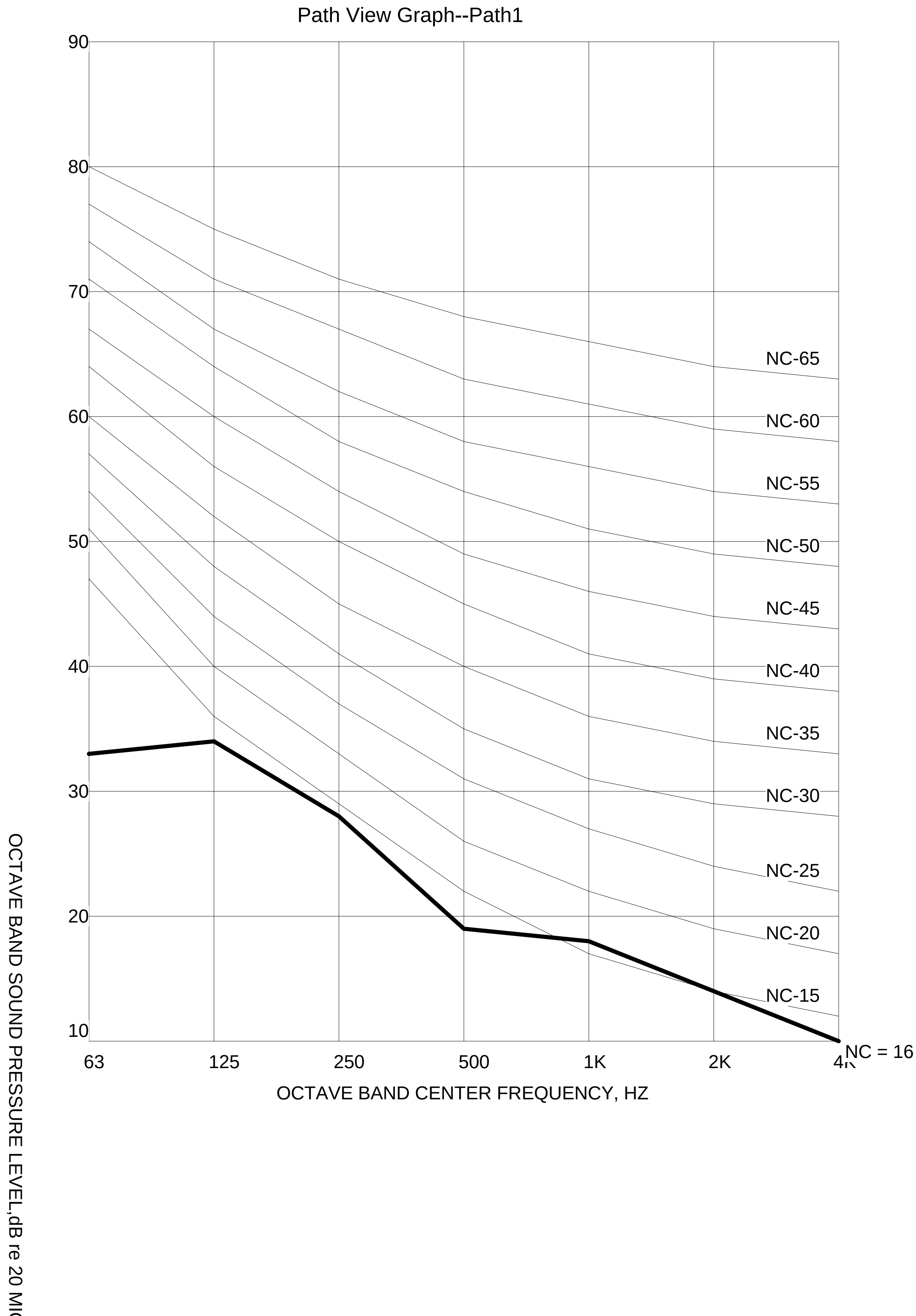
Project Name: Center For the Arts
Location: Newark, DE
Building Owner: University of Delaware
Program User: Karen Schulte
File Name: P:\THESIS\AHU2.PDT
Run Date: 03/29/06
Project Number:

Path View Graph--Path2



Trane Acoustics Program

Project Name:	Center For the Arts
Location:	Newark, DE
Building Owner:	University of Delaware
Program User:	Karen Schulte
File Name:	P:\THESIS\AHU2.PDT
Run Date:	03/29/06
Project Number:	



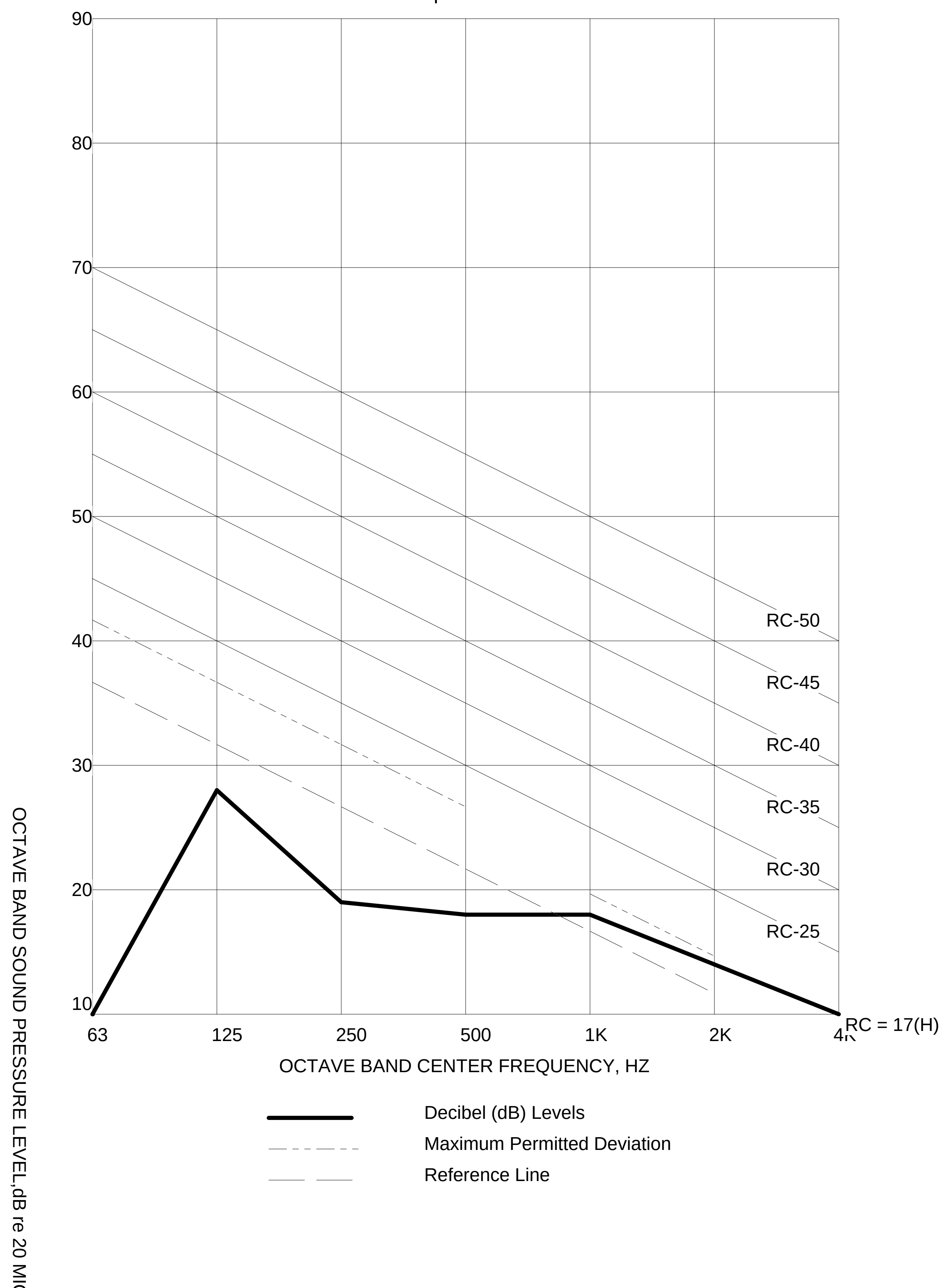
Trane Acoustics Program

University of Delaware
Center for the Arts

Karen Schulte
Mechanical Option

Project Name:	Center For the Arts
Location:	Newark, DE
Building Owner:	University of Delaware
Program User:	Karen Schulte
File Name:	P:\THESIS\AHU2.PDT
Run Date:	03/29/06
Project Number:	

Path View Graph--Path2



Trane Acoustics Program

University of Delaware
Center for the Arts

Karen Schulte
Mechanical Option

Project Name:	Center For the Arts
Location:	Newark, DE
Building Owner:	University of Delaware
Program User:	Karen Schulte
File Name:	P:\THESIS\AHU2.PDT
Run Date:	03/29/06
Project Number:	

Path View Graph--Path1